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Shaping transport infrastructure in Sub-Saharan Africa (1884-2020)

The impact of decision-making on network efficiency and sustainability: the case of Cameroon




Doctoral thesis by:
Sergio Oliete Josa

Thesis supervisor:
Francesc Magrinyà

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Cover images, from left to right:

- Construction of a railway tunnel between Douala and Yaoundé, place and dates unknown (Source: Rapport Annuel du Gouvernement Français à l'Assemblée générale des Nations Unies sur l'administration du Cameroun placé sous tutelle de la France, Année 1955, p. 141)
- Edea road-rail bridge (Source: Commission des Communautés Européennes. (1975), *Fonds Européen de Développement 1960-1975*, Direction Générale de Développement, Novembre 1975, p.18)
- Rehabilitation of the road between Garoua and Maroua, year 2013 (Source: EU Delegation in Cameroon)
- Construction of the second road-rail bridge over the Wouri River in Douala, 2016 (Source: Author)

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The impact of decision-making on network efficiency and sustainability: the case of Cameroon

by
Sergio Oliete Josa

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Thesis supervision:	Francesc Magrinyà	Universitat Politècnica de Catalunya
Thesis committee:	Adriana Haydee Martínez Reguero	Universitat Politècnica de Catalunya
	Antonio Torres Martínez	Universitat Politècnica de València
	José María Muñoz	University of Edinburgh
Substitutes:	Rodrigo Miró Recasens	Universitat Politècnica de Catalunya
	Emile Tanawa	Université de Yaoundé I

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Abstract

The objective of this research is to delve into the decision-making processes that shape the provision of transport infrastructure and to draw lessons that can contribute to policies that ensure more sustainable and efficient transport systems. To this end, it analyses the historical evolution of transport networks in Sub-Saharan Africa in the case of Cameroon over more than a century. The research explores the concept of 'infrastructure gap' and its framework, which has been in vogue over the last decade among international development actors.

The Taaffe, Morrill and Gould model (1963), Raffestin's postulates (1980) and Debrie's work on West Africa (2010) provide the conceptual framework. The thesis put forward by these authors is that the move from the desired to the physical network involves economic, political and technical compromises that take place at specific temporal and territorial scales and reflect the strategies of the dominant actors and their capacity to implement them. The theoretical maximum network is defined by the totality of the most direct relations, as if there were no constraints of any kind. The divergence between the maximum and the executed network allows operationalising the notion of infrastructure gap. Drawing from different disciplines, this research characterises the expansion and sustainability of the transport network in Cameroon and links it to the decision-making processes. The thesis defended is that the articulation between decision-making processes for network formation and the divergence between planned and implemented land transport networks in Sub-Saharan Africa can be characterised by cycles of growth and territorial scale increases, by the dialectic between networked economic development and development by networked territorial control, and by the hierarchical organisation of networks in response to lack of resources.

Firstly, there is a characterisation of the transport network growth and stagnation cycles defined by the different political regimes and colonial relationship periods. This is demonstrated through a geohistorical review of the development of the network in Cameroon, analysing the decisions taken, and through a spatial analysis of the network based on graph theory. Overall network connectivity and nodal accessibility are calculated at different stages. The *alpha*, *gamma* and *GTP* network indices and the *closeness* and *betweenness* centralities are the reference indicators.

Secondly, it is shown that, in each geohistorical period, the transport network develops according to a predominant trend in the dialectic between networked economic development (population) and development by networked territorial control (surface). For each period, it is possible to determine the pattern of network formation, which reflects the will of the groups in power. Taking advantage of the fractal properties of transport networks, in each phase, the infrastructure provision is characterised, and it is established whether there is a predominance of population distribution or surface territorial control. It is concluded that the population factor has lost weight over time and that decision-making in Cameroon progressively prioritises the expansion of the network

to cover as much territory as possible at the expense of most cities and densely populated areas.

Thirdly, the economic development of a country like Cameroon goes through an iteration between the economic growth of priority nodes and routes and the impoverishment of territories and associated nodes. To support this assertion, the role of urban centres and their accessibility in the expansion of the overall network is assessed. It is found that some nodes and regions suffer socio-economic regressions due to the prioritisation of others through preferential transport routes.

Fourthly, there is a hierarchical organisation of the transport network due to a lack of resources, which materialises in the prioritisation of the paving of certain roads in the main network. This discrepancy between the maximum and the actual transport network is the result of biased planning, funding decisions and the capacity to implement and maintain the network. To this end, the expenditure incurred in each period to develop, operate and maintain transport infrastructure in Cameroon is studied. It shows that the relative weight of infrastructure in the national budget has been decreasing while demand has been increasing. Consequently, in the case of Cameroon, the infrastructure gap is widening. Faced with reduced capacity to expand the transport network, governments must do all they can to ensure that, at the very least, it does not contract. Enforcing vehicle load regulations is an appropriate and relatively low-cost way to ensure this.

By validating these four specific hypotheses, it is shown that it is possible to characterise the evolution of the transport network in Sub-Saharan Africa, linking it to decision-making processes and quantifying how the latter affect the way in which the implemented network diverges or converges with the maximum network. Consequently, the thesis constitutes a contribution to the study of transport networks, especially in developing countries, as it provides concrete elements to quantify the increases in network scale identified by Taaffe, Morrill and Gould and to characterise the outcome of the compromise between the territorial project and the technical, political and economic capacity to implement it referred to by Raffestin and Debrie.

Resumen

El objetivo de esta investigación es profundizar en los procesos de toma de decisiones que configuran la dotación de infraestructuras de transporte y extraer lecciones que puedan contribuir a políticas que garanticen sistemas de transporte más sostenibles y eficientes. Para ello se analiza la evolución histórica de las redes de transporte en el África Subsahariana en el caso de Camerún a lo largo de más de un siglo. La investigación explora el concepto de "brecha infraestructural" y su marco de referencia, en boga durante la última década entre los actores internacionales de desarrollo.

El modelo de Taaffe, Morrill y Gould (1963), los postulados de Raffestin (1980) y el trabajo de Debrie sobre África Occidental (2010) proporcionan el marco conceptual. La tesis planteada por estos autores es que el paso de la red deseada a la red física implica compromisos económicos, políticos y técnicos que tienen lugar a escalas temporales y territoriales específicas y reflejan las estrategias de los actores dominantes y su capacidad para ponerlas en práctica. La red máxima teórica se define por la totalidad de las relaciones más directas, como si no existieran limitaciones de ningún tipo. La divergencia entre la red máxima y la red ejecutada permite operacionalizar la noción de brecha infraestructural. A partir de diferentes disciplinas, esta investigación caracteriza la expansión y la sostenibilidad de la red de transporte en Camerún y la vincula a los procesos de toma de decisiones. La tesis defendida es que la articulación entre los procesos de toma de decisiones para la formación de redes y la divergencia entre las redes de transporte terrestre planificadas y ejecutadas en el África subsahariana puede caracterizarse por ciclos de crecimiento y aumentos de escala territorial, por la dialéctica entre desarrollo económico en red y desarrollo por control territorial en red, y por la organización jerárquica de las redes en respuesta a la falta de recursos.

En primer lugar, existe una caracterización de los ciclos de crecimiento y estancamiento de las redes de transporte definida por los diferentes regímenes políticos y períodos de relación colonial. Ello se demuestra a través de una revisión geohistórica del desarrollo de la red en Camerún, analizando las decisiones tomadas, y a través de un análisis espacial de la red basado en la teoría de grafos. Se calcula la conectividad de la red global y la accesibilidad nodal en distintas fases. Los índices de red *alfa*, *gamma* y *GTP* y las centralidades *closeness* y *betweenness* son los indicadores de referencia.

En segundo lugar, se pone en evidencia que cada periodo geohistórico la red de transporte se desarrolla según una tendencia predominante en la dialéctica entre el desarrollo económico en red (población) y el desarrollo por control territorial en red (superficie). Para cada periodo, es posible determinar el patrón de formación de la red, que refleja la voluntad de los grupos que detentan el poder. Aprovechando las propiedades fractales de las redes de transporte, en cada fase se caracteriza la dotación de infraestructuras y se establece si hay predominio de la distribución de la población o bien del control territorial en superficie. Se concluye que el factor población ha perdido peso con el tiempo y que la toma de decisiones en Camerún prioriza progresivamente la

expansión de la red para cubrir el mayor territorio posible a expensas de la mayoría de las ciudades y zonas densamente pobladas.

En tercer lugar, el desarrollo económico de un país como Camerún pasa por una iteración entre el crecimiento económico de unos nodos y rutas prioritarias y el empobrecimiento de territorios y nodos asociados. Para apoyar esta afirmación, se evalúa el papel de los centros urbanos y su accesibilidad en la expansión de la red global. Se comprueba que algunos nodos y regiones sufren regresiones socioeconómicas debido a la priorización de otros mediante rutas de transporte preferentes.

En cuarto lugar, existe una jerarquización de la red de transporte debido a la falta de recursos, que se materializa en la priorización de la pavimentación de determinadas carreteras de la red principal. Esta discrepancia entre la red de transporte máxima y la real es el resultado de una planificación sesgada, de decisiones de financiación y de la capacidad de ejecución y mantenimiento de la red. Para ello se estudian los gastos incurridos en cada periodo para desarrollar, explotar y mantener las infraestructuras de transporte en Camerún. Se demuestra que el peso relativo de las infraestructuras en el presupuesto nacional ha ido disminuyendo mientras que la demanda ha aumentado. En consecuencia, en el caso de Camerún, la brecha infraestructural es cada vez mayor. Ante la reducción de la capacidad para ampliar la red de transporte, los gobiernos deben hacer todo lo posible para garantizar que, como mínimo, no se contraiga. Hacer cumplir la normativa sobre la carga de los vehículos es una forma adecuada y de relativamente bajo coste para garantizarlo.

Al validar estas cuatro hipótesis específicas, se demuestra que es posible caracterizar la evolución de la red de transporte en el África Subsahariana, vinculándola a los procesos de toma de decisiones y cuantificando cómo estos últimos afectan al modo en que la red implantada diverge o converge con la red máxima. En consecuencia, la tesis constituye una contribución al estudio de las redes de transporte, especialmente en los países en desarrollo, ya que aporta elementos concretos para cuantificar los aumentos de escala de la red identificados por Taaffe, Morrill y Gould y para caracterizar el resultado del compromiso entre el proyecto territorial y la capacidad técnica, política y económica para ponerlo en práctica al que se refieren Raffestin y Debrie.

Resum

L'objectiu d'aquesta recerca és aprofundir en els processos de presa de decisions que configuren la dotació d'infraestructures de transport i extreure lliçons que puguin contribuir a polítiques que garanteixin sistemes de transport més sostenibles i eficients. Per a això s'analitza l'evolució històrica de les xarxes de transport a l'Àfrica Subsahariana en el cas de Camerun al llarg de més d'un segle. La recerca explora el concepte de "bretxa infraestructural" i el seu marc de referència, en voga durant l'última dècada entre els actors internacionals de desenvolupament.

El model de Taaffe, Morrill i Gould (1963), els postulats de Raffestin (1980) i el treball de Debrie sobre Àfrica Occidental (2010) proporcionen el marc conceptual. La tesi plantejada per aquests autors és que el pas de la xarxa desitjada a la xarxa física implica compromisos econòmics, polítics i tècnics que tenen lloc a escales temporals i territorials específiques i reflecteixen les estratègies dels actors dominants i la seva capacitat per a posar-les en pràctica. La xarxa màxima teòrica es defineix per la totalitat de les relacions més directes, com si no existissin limitacions de cap mena. La divergència entre la xarxa màxima i la xarxa executada permet operacionalitzar la noció de bretxa infraestructural. A partir de diferents disciplines, aquesta recerca caracteritza l'expansió i la sostenibilitat de la xarxa de transport a Camerun i la vincula als processos de presa de decisions. La tesi defensada és que l'articulació entre els processos de presa de decisions per a la formació de xarxes i la divergència entre les xarxes de transport terrestre planificades i executades a l'Àfrica subsahariana pot caracteritzar-se per cicles de creixement i augments d'escala territorial, per la dialèctica entre desenvolupament econòmic en xarxa i desenvolupament per control territorial en xarxa, i per l'organització jeràrquica de les xarxes en resposta a la falta de recursos.

En primer lloc, existeix una caracterització dels cicles de creixement i estancament de les xarxes de transport definida pels diferents règims polítics i períodes de relació colonial. Això es demostra a través d'una revisió geohistòrica del desenvolupament de la xarxa a Camerun, analitzant les decisions preses, i a través d'una anàlisi espacial de la xarxa basat en la teoria de grafs. Es calcula la connectivitat de la xarxa global i l'accessibilitat nodal en diferents fases. Els índexs de xarxa *alfa*, *gamma* i *GTP* i les centralitats *closeness* i *betweenness* són els indicadors de referència.

En segon lloc, es posa en evidència que cada període geohistòric la xarxa de transport es desenvolupa segons una tendència predominant en la dialèctica entre el desenvolupament econòmic en xarxa (població) i el desenvolupament per control territorial en xarxa (superfície). Per a cada període, és possible determinar el patró de formació de la xarxa, que reflecteix la voluntat dels grups que posseeixen el poder. Aprofitant les propietats fractals de les xarxes de transport, en cada fase es caracteritza la dotació d'infraestructures i se estableix si hi ha un predomini de la distribució de la població o bé del control territorial en superfície. Es conclou que el factor població ha perdut pes amb el temps i que la presa de decisions a Camerun prioritza progressivament

l'expansió de la xarxa per a cobrir el major territori possible a costa de la majoria de les ciutats i zones densament poblades.

En tercer lloc, el desenvolupament econòmic d'un país com Camerun passa per una iteració entre el creixement econòmic d'uns nodes i rutes prioritàries i l'empobriment de territoris i nodes associats. Per a donar suport a aquesta afirmació, s'avalua el paper dels centres urbans i la seva accessibilitat en l'expansió de la xarxa global. Es comprova que alguns nodes i regions sofreixen regressions socioeconòmiques a causa de la priorització d'uns altres mitjançant rutes de transport preferents.

En quart lloc, existeix una jerarquització de la xarxa de transport degut a la falta de recursos, que es materialitza en la priorització de la pavimentació de determinades carreteres de la xarxa principal. Aquesta discrepància entre la xarxa de transport màxima i la real és el resultat d'una planificació esbiaixada, de decisions de finançament i de la capacitat d'execució i manteniment de la xarxa. Per a això s'estudien les despeses incorregudes en cada període per a desenvolupar, explotar i mantenir les infraestructures de transport a Camerun. Es demostra que el pes relatiu de les infraestructures en el pressupost nacional ha anat disminuint mentre que la demanda ha augmentat. En conseqüència, en el cas de Camerun, la bretxa infrastructural és cada vegada major. Davant la reducció de la capacitat per a ampliar la xarxa de transport, els governs han de fer tot el possible per a garantir que, com a mínim, no es contregui. Fer complir la normativa sobre la càrrega dels vehicles és una forma adequada i de relativament baix cost per a garantir-ho.

En validar aquestes quatre hipòtesis específiques, es demostra que és possible caracteritzar l'evolució de la xarxa de transport a l'Àfrica Subsahariana, vinculant-la als processos de presa de decisions i quantificant com aquests últims afecten la manera en què la xarxa implantada divergeix o convergeix amb la xarxa màxima. En conseqüència, la tesi constitueix una contribució a l'estudi de les xarxes de transport, especialment als països en desenvolupament, ja que aporta elements concrets per a quantificar els augments d'escala de la xarxa identificats per Taaffe, Morrill i Gould i per a caracteritzar el resultat del compromís entre el projecte territorial i la capacitat tècnica, política i econòmica per a posar-lo en pràctica al qual es refereixen Raffestin i Debrie.

Contents

List of Figures

List of Tables

1. Introduction

Since the independence of Sub-Saharan African countries, the root causes of their underdevelopment, and possible solutions, have been the subject of many studies, both by academics and international aid agencies. During these sixty years, little progress has been made in reducing the infrastructural backlog left by the colonial powers. Among the reports describing the current state of African infrastructure, one can cite Foster & Briceño-Garmendia, 2010, Gutman, Sy & Chattopadhyay, 2015 and Lakmeeharan, Manji, Nyairo & Poeltner, 2020. In the literature about developing countries, the notion of the infrastructure gap was introduced by Hilling (1970) to describe a vicious cycle where infrastructure is not considered viable because there is no demand to use it and, at the same time, demand is not generated because the necessary infrastructure to produce it is lacking. However, it was not until the 2010s[1], and specifically after the adoption of the Addis Ababa Action Agenda[2] in 2015, that the term "infrastructure gap" was widely used in the framework of international development policies.

The concept of infrastructure gap evokes the discrepancy between the infrastructure that should be and the infrastructure that exists. Therefore, it is necessary to understand what the scientific literature and development policy documents say about this gap and what they envisage to narrow it. A first glance at the current documents referring to the infrastructure gap or financing gap shows that it is generally determined as the difference between infrastructure investment needs and actual spending. However, the difficulty lies precisely in determining what these infrastructural needs are:

- Is it about providing African countries with the same levels of service as the most developed countries? Or building infrastructure comparable to that of other emerging regions such as the Asian countries?

- Who set the standards that determined the ideal infrastructure network in each historical period? Were they the result of an external vision of the colonial power or the international donor, or were they a response to the needs of local users and their rulers?

- Is the ideal network based on an extractive vision of raw materials and agricultural products or does it take into account industrialisation factors? Are other elements such as poverty and inequality reduction, cities location, conflict zones, environmental protection, etc. taken into account?

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[1] See Google Books Ngram Viewer: https://books.google.com/ngrams/graph?content=infrastructure+gap&year_start=1960&year_end=2019&corpus=26&smoothing=0

[2] https://developmentfinance.un.org/closing-the-infrastructure-gap

As the above-mentioned documents show, one of the most obvious manifestations of this infrastructural gap is the transport network. The starting point for this research is the desire to consider better asset management in the context of the current precariousness of transport networks (the subject) in Sub-Saharan Africa (the object). While modern transport networks have evolved over several centuries in most parts of the world, in Africa, reaching the current configuration has taken just over a hundred years. It does not mean that transport networks did not exist prior to colonisation (Soi, 2022). However, as some authors have shown (Taaffe, Morrill and Gould 1963; Hoyle, 1973; Rimmer, 1977; Pedersen, 2003; Debrie, 2010), maritime transport and the extraction of raw materials radically changed the flows and imposed new routes. Today, many of these networks have reached completeness and now interconnect all the main urban centres or district capitals. However, the condition of the infrastructure is far from the one to which it was designed. Road deterioration is rapid and some existing links even become impassable for long periods. The rail network, decrepit, unconnected, mostly not electrified and with multiple gauges, is struggling to expand and is even contracting. At the same time, transport policies are heavily influenced by national and pan-African political aspirations to modernise the continent with highways and high-speed trains interconnecting all capital cities. In this framework, and more recently, a growing Chinese influence is changing the rules of the game (Taylor and Zajontz, 2020).

Among the factors contributing to the poor performance of transport systems in Sub-Saharan Africa, this research is interested in the policies and decisions taken to expand the networks, their actual realisation and the consequences of these choices in space and time. In general, the classical decision-making of infrastructure projects is based on cost-benefit analysis. However, the economic impacts are much wider over time and cannot only be captured in terms of travel time or vehicle operating costs savings at a given time. Roberts *et al* (2020) point out that outcomes are much wider and include general economic prosperity (monetary measures of well-being such as income, wages, and consumption), social inclusion (employment and gender), equity (poverty, inequality and territorial imbalances), environmental impact (emissions, pollution and deforestation) and infrastructure resilience. In addition, the fixed nature of transport infrastructure creates strong path dependency on the chosen route.

In the case of Sub-Saharan Africa, where most of the territories were void of any modern infrastructure until the colonisation, the "structuring effects" of transport are a decisive factor of territorialisation (Steck, 2009). Therefore, the choice of an investment has generally major implications for the future of the country. If a chosen solution is not efficient, the forthcoming generations will probably be unable to remediate it. With the limited amount of funding available, if one road is chosen and not another, an option with higher economic benefits may have been missed and postponed indefinitely. A wrong choice can trigger a decision trap where the government is caught up in a spiral of bad spending just because the project has to be finished (Hirschman, 1967; Flyvbjerg, 2016). An additional investment implies budgetary resources and/or new debt and more maintenance expenses. It will also require more human resources and will increase the workload of the public administration. In the worst case, as it usually happens in Sub-Saharan Africa, the additional resources needed do not exist and the new project will simply divert funds and staff that could have been allocated for other purposes.

With the objective of formulating recommendations contributing to improve future transport policies, the focus of the thesis is the impact of decision-making on the spatial efficiency of the network and the sustainability of the road investments. In this regard, we pose the following overall *research question* that can be formulated as follows:

Research question: In Sub-Saharan African countries, over time, how close is the ideal transport network to the actual network? Is the transport network adequately spatially serving the economic, political and social needs of the corresponding period?

As we will see in this thesis, the efficiency of the network is understood as the convergence between the ideal or maximum network and its actual implementation (Raffestin, 1980, pp. 263-285) and can be measured under multiple dimensions. For example, through graph theory indicators (alpha and gamma indexes, detour index, shortest paths length...), by the distribution of infrastructure provision (road/rail density per surface or per inhabitants, accessibility, productive areas...) or by the possibility or constraint of multimodality (split rail/road).

Based on this research question, and in line with the work of Raffestin just referenced, we can put forward the following preliminary hypothesis that we will have to confirm when we review the state of the art:

In Sub-Saharan Africa, the gap between the ideal and the executed transport network is a consequence of decision-making processes derived from the successive strategies of power of the dominant actors at each temporal and spatial scale.

If an answer can be given to this research question and we can support the above assertion, then we will contribute to achieving the objective of this research:

Objective of the research: To raise awareness among current decision-makers of the long-term consequences of measures taken to expand the transport networks in Sub-Saharan Africa and provide tools to improve their efficiency and sustainability.

This research is therefore policy-oriented. By providing evidence from the mistakes and good decisions made in the past, the thesis seeks to objectify the effects and consequences of this decision-making on the planning of structures and at the same time on the continuity in the maintenance of the executed infrastructures. The sustainability of road investments relates to the capacity of road authorities to protect and maintain roads up to the number of years to which they were designed. It is important to analyse road maintenance costs since regular or premature degradation of existing infrastructure affects the planning and implementation of a new network. The aim is to make decision-makers aware of the choices that were made in the past in order to avoid repeating bad/irreversible decisions and to encourage and expand good practices that enhance the sustainability of the networks.

1.1. Case study research

There are several challenges in considering the whole of Sub-Saharan Africa as an object of study. First, Sub-Saharan Africa represents 48 out of the 55 African countries, some of them being islands or archipelagos. Second, as we will see in the state of the art, various studies have a narrow scope by focusing on the Sub-Saharan African reality without putting the transport issue in the world context, not only the current one, but also historical. Third, there are few works linking general theories, or at continental scale, with the national level in Sub-Saharan Africa.

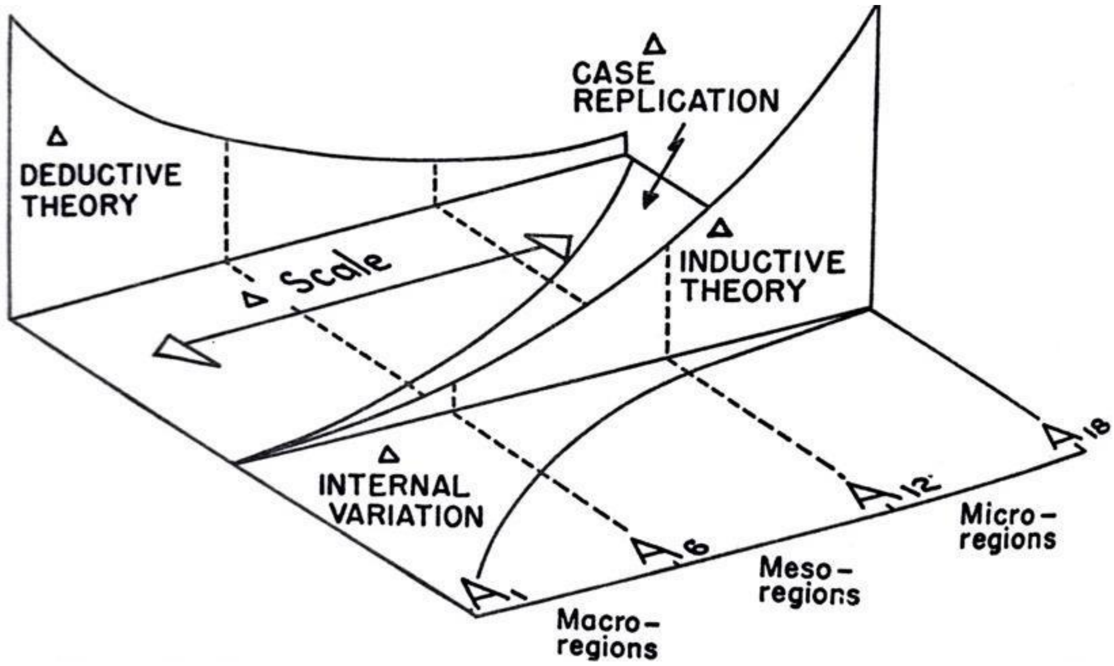


Figure 1.1. Implications of scale for geographical analysis (Chorley and Haggett, 1965)

The appropriate correspondence between scale and theory is a constant question in geographical analysis. To explain the implications of scale, Chorley and Haggett (1965), propose the diagram shown in figure 1.1. The horizontal plane shows two concurrent logics of change in scale: the increase in the number of potential cases and the decrease in complexity as the regions become smaller. These in turn lead to the changes shown in the vertical plane. These are the increase in comparability, replication of cases, and therefore levels of significance of results as regions become smaller, while on the contrary, as regions become larger, there are fewer cases to compare and explanations have to rely more and more on external analogies.

To address this complexity, this thesis proposes a case study research. Case study is an appropriate methodology in intervention-oriented fields of research (Johansson, 2003). Given the multidisciplinary nature of transport policy, professional practice is mainly based on a combination of theoretical research and knowledge of a range of cases, which in turn are based on personal experience or are model cases established in the profession. According to Yin (1994), the technical definition of a case study contains two parts:

1. A case study is an empirical investigation that studies a contemporary phenomenon in its real context, especially when the boundaries between the phenomenon and the context are not obvious.

   This definition allows us to make a first difference between case studies and other research strategies. Given the difficulties in distinguishing between phenomenon and context in real-life situations, a second definition is necessary:

2. The case study faces the situation in which there are many more relevant variables than data available and, therefore, it depends on multiple sources of information that provide the necessary data to converge in a triangulation procedure.

Another feature of the case study is that it benefits from prior theoretical development to guide data collection and analysis.

Therefore, the case study is a research strategy that attempts to be comprehensive and integrate different approaches to data collection and analysis. In this respect, Johansson (2003) explains that the case study is a "meta-method", that is, a procedure that relies on other methods and additional parameters to become a research method in its own right.

Stake (1995) classifies case studies as follows:

1. Intrinsic: The researcher has an interest in a particular case.

2. Instrumental: The objective of the research is not only to understand the case being studied, but also to answer a specific research question.

3. Collective: Case studies consist of a set of individual cases.

In the case of the present doctoral research, we will use the case study from the instrumental perspective, to understand a concrete case and answer a research question.

For Tellis (1997), simple case studies are used to confirm or challenge a theory, or they may represent a single or extreme case. They are also ideal for a telling case where an observer is able to gain access to a phenomenon that was previously inaccessible. However, a frequent criticism of the case study methodology is precisely that its dependence on a single case makes it poorly able to provide generalizable conclusions.

An important aspect of the case study methodology is how the cases to be studied are selected. A case study focuses on a single unit of analysis but, at the same time, it takes into consideration the context and therefore encompasses many variables. Johansson described this strategy as "explanatory" in contrast to the "experimental" approach, with a single unit of analysis and very few isolated variables, and the "reductive" approach, with many units of analysis and very few variables. Figure 1.2 shows three strategies to focus empirical research by reducing the units of analysis (cases), or the number of variables (qualities), or a combination of the two. The three strategies imply different methodologies. Case studies are implied by an explicative strategy.

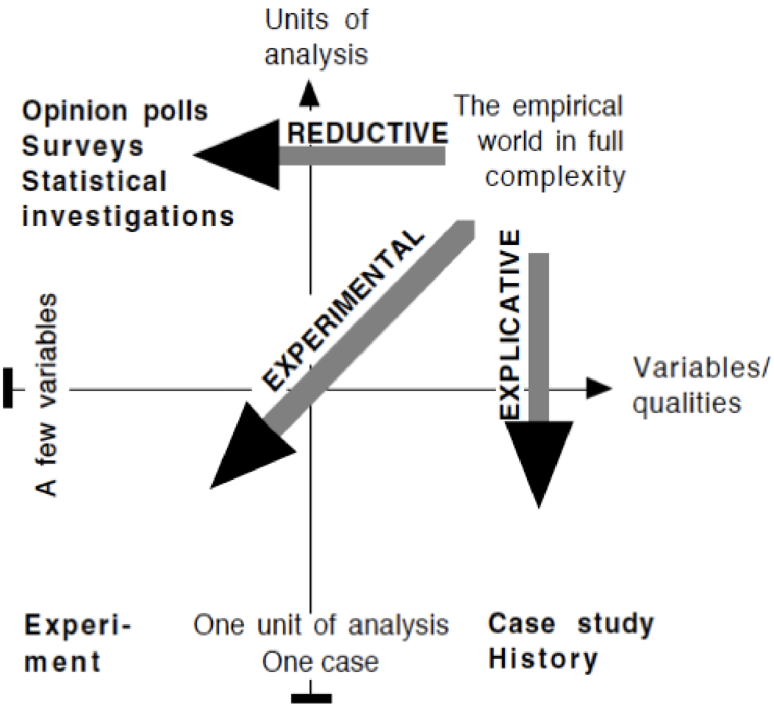


Figure 1.2. Three strategies to focus empirical research (Johansson, 2003)

The case could therefore be proposed and studied because there is an intrinsic interest in the case itself. On the other hand, it could be chosen expressly or analytically because it is, for example, informative, critical, revealing, unique or extreme (in contrast to the representative sample strategy used in statistical research) (Stake, 1995; Patton, 1990).

Another fundamental aspect to consider is the validation of case study research results. What all the case studies have in common is that they were validated by triangulation. Very frequently, data collection methods are triangulated, which involves a combination of different methodologies. In addition, information sources, theories or research can also be triangulated.

Finally, a key question of the case study is how generalisations are made from a single case. Generalisation from a single case is analytical, not statistical. According to Johansson, generalisation can be made in four different ways (see table 1.1). The first is by testing the hypotheses in a particular case and, as a result, determining the domain in which the theory is valid. The second form of generalisation is the generation of the theory through an inductive approach: the conceptualization is based on the facts of the case. The result is a theory at the micro level formed by related concepts. The third method is "naturalistic" generalisation. In these cases, generalisations are made from known cases and applied to the problem to be studied by making appropriate comparisons (Stake, 1995). The last method consists in synthesising a case, when a case is created (reconstructed) by a process of abductive reasoning from a few facts; for instance, historical data or clues.

Procedure	Mode of reasoning	Result	Generalisation
Hypothesis testing A theory (hypothesis) is tested in a case, and validated or falsified by deductions	Deductive	The establishment of the domain of the theory	From a hypothesis and facts to the verification of a *theory*
Theory generating A principle (theory) is generated from facts in this case	Inductive	A theory (conceptualisation)	From facts in a case to *theory*
Naturalistic generalisation An actual problem situation is compared with known cases	Abductive	Ability to act based on the conception of a case (or cases)	From cases to a *case*
Synthesising a case A case is synthesised from facts in the case and a principle (theory)	Abductive	The (re)construction of a case	From cases and theory to a *case*

Table 1.1. Modes of generalisation and reasoning in case studies (Johansson, 2003)

However, Johansson (2003) concludes that the essence of case study methodology is triangulation, the combination at different levels of techniques, methods, strategies or theories. Case studies develop through such association of qualitative and quantitative methods and their generalisation should be possible by combining different modes of generalisation. Flyvbjerg (2006) emphasises the strategic importance of the choice of the case to increase its generalizability.

As will be explained in more detail in chapter 3, the case of Cameroon is appropriate to validate our thesis and generalise it because it is a good compromise between a country scale and a regional scale. As a sufficiently large and diverse country, it allows conclusions to be extrapolated more easily to a larger scale. Geographically, it covers a region going from the Sahelian territories on the Lake Chad side to humid tropical forests in the south and gives sea access to vast areas of the Sahel and central Africa, including the two landlocked countries of Chad and Central African Republic. Culturally and ethnographically, it has a great diversity and is a junction between the Muslim Hausa-Fulani and the Christian/Animist Bantu people. Historically, it has been colonised by three European powers (Germany, first, and, then, France and UK). For all these reasons, Cameroon is popularly referred to as "Africa in miniature"[3]. In addition, Cameroon contains a transport corridor, the Douala-N'djamena-Bangui corridor, which is of continental value, as it unlocks the neighbouring countries of Chad and the Central African Republic, while most of its itinerary is in Cameroon.

The case study methodology used in this thesis will be instrumental in explaining how the discrepancies between the ideal transport network and the executed one materialise. We will examine past choices made in territories that have been newly shaped by transport infrastructure. These decisions have been made to the detriment to other crucial investments, and it may have constrained a coherent development of the network and could have created geographical imbalances. While the specific object of the study is Cameroon, the thesis will maintain the perspective given by the general object, which is the whole of Sub-Saharan Africa. Therefore, the thesis includes an extensive documentary work to study the transport networks at continental level. Largely, the conclusions from that continental part of the thesis should be directly inferred from bringing together contributions from the existing research works. Part of them will be corroborated with general theories on transport and territories developed from the study in Africa and in other continents. Others will need to be further tested and validated by our case study. This thesis therefore starts from the study of the country level, i.e. Cameroon limited by its borders, but also with the ambition of improving the understanding of both the regional level, that of Central Africa and neighbouring Nigeria, and the continental level.

1.2. Compendium of publications or full thesis report?

This doctoral research has been conceived as a compendium of publications, corresponding to what is stipulated in the UPC regulations on article-based theses[4]. However, in order to allow a better understanding of the research carried out, this report includes, in addition to the published works, the detailed analysis conducted for the case of Cameroon. Therefore, the present document can also be considered as a traditional full doctoral dissertation.

As explained above, while focusing on Cameroon, this research looks at different scales. Therefore, the works that make up this thesis have the logic of going from the country level to the more general, at the continental level, and, then, to the more specific, at the scale of a transport corridor. This approach of alternating the scale of research is the result of the iterative nature of doctoral research work, in which the doctoral student

[3] https://www.bbc.com/news/world-africa-13146029

[4] Normativa per a presentar la tesi doctoral com a compendi de publicacions. Programa de Doctorat: Enginyeria i Infraestructures del Transport. Document aprovat per la Comissió Permanent de l'Escola de Doctorat el 29/11/2016.

comes to the conclusion that there is a need to zoom in and then zoom out according to the findings obtained as the research progresses.

The published works should be read in the following order:

1. Oliete Josa, S., & Magrinyà, F. (2018). Patchwork in an interconnected world: the challenges of transport networks in Sub-Saharan Africa. *Transport Reviews*, 38(6), 710-736. Print ISSN: 0144-1647 Online ISSN: 1464-5327. https://doi.org/10.1080/01441647.2017.1414899

2. Oliete Josa S. & Magrinyà F. (2022). From Priority Projects to Corridor Approaches: The African and European Continental Transport Networks put into Perspective, in Nugent P. Lamarque H. (eds.), *Transport Corridors in Africa*, Edited Volume, Boydell and Brewer, Suffolk https://boydellandbrewer.com/9781800104778/transport-corridors-in-africa/

3. Torres Martínez A.J., Oliete Josa S., Magrinyà F. & Gauthier J.M. (2018). Cost-effectiveness of enforcing axle-load regulations: The Douala-N'Djamena corridor in Sub-Saharan Africa, *Transportation Research Part A: Policy and Practice*, Volume 107, 216-228, ISSN 0965-8564. https://doi.org/10.1016/j.tra.2017.11.016

The first article published in *Transport Reviews* in 2018 and the book chapter, publications 1 and 2 above, study the transport networks in Africa at continental level. The second paper, publication 3, published in *Transportation Research Part A* in 2018, analyses transport sustainability along the corridor level Douala-N'djamena and which runs mostly in Cameroon.

Moreover, as we shall see, this thesis draws on a research report published in 2022 and an indexed journal paper about transport corridors in Africa that the author has produced as part of his professional activities:

4. Baranzelli, C., Kucas, A., Kavalov, B., Maistrali, A., Kompil, M., Oliete Josa, S., Parolin, M. and Lavalle, C. (2022). *Identification, characterisation and ranking of strategic corridors in Africa*, EUR 31069 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-76-52430-4, doi:10.2760/498757, JRC128942. https://publications.jrc.ec.europa.eu/repository/handle/JRC128942

5. Baranzelli, C., Blengini, G. A., Oliete Josa, S., & Lavalle, C. (2022). EU–Africa Strategic Corridors and critical raw materials: two-way approach to regional development and security of supply. *International Journal of Mining, Reclamation and Environment*, *36*(9), 607-623. https://www.tandfonline.com/doi/full/10.1080/17480930.2022.2124786

The author intends to publish another article in an indexed journal after the defence of the thesis. This last paper will focus on the case of Cameroon and will highlight the geohistorical review, the topological study of the network and the infrastructure provision analysis carried out in this thesis. It will be, in fact, its synthesis.

This doctoral thesis dissertation is structured according to the conventional sequence of: i) state of the art, ii) theoretical framework, iii) methodology, iv) analysis and results and v) conclusions. After chapter 2, which reviews the state of the art of the research, chapter 3 justifies and explains the reasons of the theoretical framework and the methodology and analytical tools chosen. The research part of thesis is developed using five distinct approaches, which are developed in chapters 4 to 7:

1. Chapter 4 identifies the network evolutionary phases establishing three main periods (colonial, national, regional) and the respective subdivisions and characteristics. A geohistorical review of the development of the transport network in Cameroon between 1884 and 2020 is conducted. It also looks at continental level and includes a summary of the conclusions of our paper published in *Transport Reviews* in 2018.

   The chapter has two parts. First, it describes the main historical events affecting the transport network. This review is based on official documents and other bibliographic sources. Second, it characterises the network in relation to the maps and economic conditions prevailing in each period, looking in particular at the main products exported. For this, the network has been mapped retrospectively in selected years, from 1930 to 2015.

2. In chapter 5, the thesis uses classic quantitative measures of transport geography to describe the topological structure of the network. It studies the evolution of the network over time using spatial analysis tools and graph theory measures. The aim is to characterise the evolution of the transport infrastructure network and the topology generated in the territory to evaluate the links and the nodes of the territory prioritised at each stage.

   The characterisation of the phases is defined according to a transversal reading of the methodologies of graph theory, fractal theory, Taaffe, Morrill and Gould's phases and Debrie's evolutionary instruments. In these mechanisms, a dialectic phenomenon is produced: a global vision versus a local vision of the network. The moments of globalisation to be analysed are the colonial, the national and the regional periods.

3. Once the evolutionary stages of the network have been characterised, chapter 6 evaluates the dialectic between the development that prioritises economic activity and population and the desire to redistribute wealth and territorial control, where surface coverage predominates. In parallel, extractive policies coexist with logics for the generation of urban and territorial services. It is worth mentioning that in this process there is a phenomenon of a movement from the countryside to the city with an evolution in the distribution of population and poverty. The thesis tries to

characterise these variables with the evolution of the distribution of the road network and its paving.

The research takes into consideration territorial features based on demography and economic development indices. It looks at how transport infrastructure is organised across the territory in relation to the population. The objective is to establish the correlation between the provision of infrastructure over the years and the levels of development of the population and its economic activity. For this purpose, it uses common infrastructure density indicators and applies a method based on the fractal theory. Those indicators are compared with the existing poverty rates over time in the different regions. The thesis also looks at the Cameroonian system of cities. The aim of this analysis is to complement the study of the provision of infrastructure with a characterization of the urban centres and its historical dynamics. It looks at how the quality of the road network around the main cities has evolved.

4. Infrastructure investment is a fixed capital investment where its financing is characterised by the availability of resources associated with taxation and borrowing. It is not only about financing infrastructure, but also about its maintenance. Chapter 7 analyses economic data related to investment in the sector over time. It estimates past levels of investment in the transport sector in relation to the public revenues and compares them with the current situation. The projected costs necessary to maintain the road network in good condition are also studied and compared with the costs actually incurred. Finally, this chapter studies the lifespan of asphalt roads in Cameroon and the impact of heavy vehicle traffic on road deterioration. It corresponds to the paper we published in 2018 in *Transportation Research Part A.* It analyses the axle-load regulations, how they are enforced and their benefits on the Douala-N'Djamena international road, which is the main transport corridor in Central Africa and the backbone for internal transport in Cameroon.

These five analytical chapters of the research lead to partial results that are discussed together, crosschecked and consolidated in chapter 8. The purpose is to see if the thesis has been able to test the hypothesis raised by cross checking the conclusions obtained for the specific case of Cameroon with the ones anticipated. As a result, the last part containing the conclusions will serve to summarise and generalise the main contributions of the thesis and to highlight lessons learnt and recommendations that can be used for policymaking in Sub-Saharan Africa. Finally, further research will be proposed. The literature would benefit from research on other countries to gain insights into the network development in different country contexts.

2. State of the art

The study of transport in Sub-Saharan Africa, necessarily interdisciplinary, has been developed under different perspectives in such a way that their boundaries imbricate and conceptual and theoretical feedback is constant. Disciplines like economic geography and transport geography have highly influenced intervention-oriented fields, like planning and civil engineering, and vice versa. In turn, political actors and public servants have tried to justify their decisions with the support of appraisal tools developed by engineers and planners. Thus, the state of the art looks at all these linkages, including those with social sciences, with a particular attention to the connections between the academic world and the political arena. In total, we have identified four disciplines that frame the issue of transport in Africa from different perspectives:

1. Economic and political systems
2. Economic geography
3. Transport and urban geography
4. Economic impact of transport investments

The compilation of the state-of-the-art information does not pretend to be, and cannot be, exhaustive, as a paradox is observed: the existence of a very extensive literature on transport networks in both developed and developing countries, and in Sub-Saharan Africa in general, but very little works at country level in Sub-Saharan Africa. Since, as we have explained, our research strategy is based on studying the case of Cameroon, reviewing the state of the art should be a compromise between the generic literature, specific works on Sub-Saharan Africa and the study of the transport networks in that country. Accordingly, our review of the research achieved in the field of transport infrastructure is selective and focuses on elements that are relevant for the Sub-Saharan African context that can applied to the Cameroon case study.

2.1. Transport infrastructure in African economic and political systems

Transport infrastructure is very much present in studies on economic regimes, especially regarding colonial systems. Transport was at the heart of the economic calculations of the colonial powers, since the occupation was justified above all by the extraction of raw materials. As Young (1994) explains, for colonial powers, capital investments were justified, at first, to access areas with high economic value. The prevailing principle was that colonies had to be self-sufficient, with minimal administration. Coquery-Vidrovitch (1976) describes the origin of contemporary underdevelopment, which, according to her, in the French colonies, started in the 1930's because of the protectionist policies that accompanied the Great Depression. It implied the substitution of the "*économie de traite*" by monocultures and the assumption of responsibility for infrastructure equipment by the public sector of the colonial territories, leading to the establishment of the vicious cycle of aid and indebtedness. This also led to an impoverishment of the rural areas and the beginning of an urban migratory influx. In addition, Huillery (2014) proves that, for France, colonisation costs were negligible (0.29 percent of French annual expenditures, including 0.24 percent for military and central administration and 0.05 percent for French West Africa's development). The burden was imposed on African taxpayers, in part, because the cost of the French colonial public servants was very high.

Between the end of the Second World War and the final years of colonialism, self-sufficiency policies had been progressively replaced by the ideology of developmentalism (Wallerstein, 2005). When studying how power has been exercised in Africa by comparing different African countries, Herbst (2000) pays particular attention to the issue of transport infrastructure and its financing. He explains that the existing transport discontinuities in distant regions were seen as administrative divisions of colonial space. At the end of the colonial period, the partition of the African territories into "artificial states" fragmented the territory and exacerbated pre-existing geographical hindrances (Alesina, Easterly, & Matuszeski, 2011). As Sub-Saharan Africa had rates of urbanisation below 15%, and cities were of small size in general, a major consequence of this population pattern was that colonial governments were unable to collect significant taxes from individuals and opted to rely essentially on custom duties (Herbst, 2000). Colonial policies had had the final consequence of virtually dismantling the local private sector, and Western countries continued to look down on its entrepreneurial capacity. Because of the extractive colonial policies, economies of the independent countries had been born deficiently industrialised and highly dependent on export-oriented resources. Vast amounts of public investment were needed to develop, especially in infrastructure projects, and savings accumulated over previous decades were spent (*Ibid.*).

Clapham (1996) argues that political leaders of the newly independent states, in a conjunction of pragmatism, lack of capacity and desire to preserve their privileges, readily adopted the pre-existing economic model, allowing for the emergence of "rentier states", where most of the revenues derived from the rent of natural resources to foreign interests. To understand better this mechanism in the African political systems, it is key to refer to the concept of "neopatrimonialism" (Médard, 1990; Chabal & Daloz, 1999). In the 1980s and 1990s, in the face of growing economic crisis and misgovernment, African leaders, in order to adapt to structural adjustment programmes, relied on traditional social relations to find ways to translate social disorder into patronage resources to shore up the loyalty of their clientelism networks. These political systems, that Bayart (1989) described as the "*politique du ventre*'' (politics of the belly) still predominate today in many parts of Africa. However, the prevalence of neopatrimonialism practices is not synonymous with chaos. To this day, it coexists and reinforces an interventionist and planning state that rules under budgetary constraints through technical plans and investments (Samuel, 2017).

European ambitions in Africa did not end with the independence of the colonial territories. The aftermath of the Second World War also favoured the resurgence of

Eurafrican ideals. The creation of a homogeneous and coherent transport system between Europe and Africa, including the realisation of the trans-Saharan railway from the Mediterranean to the Niger River, was seen as a precondition to establishing the Eurafrica region (Guernier, 1957). Despite failing to receive an official endorsement (Dramé & Saul, 2004), these ideals had a decisive influence on the Yaoundé Convention signed in 1963, which defined the principles of the multilateral association between Africa and Europe (Hansen & Jonsson, 2014). Since then, Europe has contributed to finance a significant part of African transport infrastructure. However, this development aid to African countries must be understood within the framework of global capitalist relations, beyond geopolitical or altruistic reasons.

The dependence on raw materials exports, the lack of infrastructure, the low education levels, the poverty in the rural areas and the absence of industrialisation sunk most of the new African countries into the trap of underdevelopment and poor governance. According to Wallerstein (2004), in the second half of the twentieth century, the global capitalist system was characterised by a core-periphery structure, in which developed countries (the core) dominate and exploit developing countries (the periphery) for their resources and labour. He claims that the extraction of raw materials from developing countries emphasises the exploitative nature of the global capitalist system as is accompanied by a process of unequal exchange, in which developed countries pay low prices for these resources and reap most of the benefits of their production and sale.

Since the World Bank began its operations in 1945, capital markets have had a great influence on the proliferation of new multilateral development banks (MDBs) (Kellerman, 2019). MDBs leverage financial sources in the capital markets, allowing them to absorb surplus capital by increasing lending to developing countries. This is a direct consequence of the accumulation logic of the capitalist system, as Harvey (2012) points out. Several works analyse the impact that MDBs institutional culture and lending practices have on the quality of the investments. Laïdi (1989) provides a comprehensive analysis of the political economy that underlies the World Bank's policies and its lending practices. He explains how, in the wake of strong US influence and neoliberal ideology, the Bank has been able to adapt its discourse integrating broader poverty alleviation and social inclusiveness objectives. The crux of the matter was the recurrent need to find projects to fund. Despite frequent criticisms, particularly on the lack of qualified human resources and institutional capacity of low-income countries to absorb large amounts of foreign aid, the World Bank expanded in Africa because the new states were seen as an opportunity to expand its lending activities (Fisette, 1997). Several authors (Babb, 2009; Gould, 2006; Humphrey, 2016, Kellerman 2019) highlight the pressure for keeping lending activities at strategic levels and to ensure financial soundness (and AAA rating), to the detriment of development objectives and good governance. The negative effects of irresponsible lending, like illegitimate or excessive debt or bad projects ("white elephants"), has been observed by some authors (Winters, 2002; Robinson & Torvik, 2005).

The reasons for the poor economic performance of Sub-Saharan countries were detailed in a 1981 World Bank report known as the Berg Report. This report proposed a new strategy to rectify the existing situation by identifying "major policy actions central to any growth-oriented programme: more suitable trade and exchange rate policies; increased efficiency of resource use in the public sector; and improvement in agricultural policies". The Berg Report positioned the World Bank as the "dominant source of economic and policy analysis for Sub-Saharan Africa" (Sander, 2002) and became the "immediate intellectual precursor to the introduction of the structural adjustment programmes (SAPs)" (Mkandawire & Soludo, 1998) largely assumed in the 1980s by international financial institutions, bilateral donors and governments in Africa.

Since the 2000s, a major feature in the African infrastructure sector is the surge of Chinese investment. Although other significant non-OECD financiers have also become relevant (Turkey, India, Brazil…), China has multiplied development aid with a specific focus on resource-rich Sub-Saharan countries (Foster & Briceño-Garmendia, 2010). China's investments in the transport sector are mostly centred on international links. Bonfatti and Poelhekke (2017) provide some evidence on a bias towards reinforcing Africa's interior-to-coast transport network, probably obeying to mining interests. Overall, China has a strong political influence affecting trade patterns and investments (Taylor and Zajontz, 2020). Corkin, Burke, and Davies (2008) describe the intervention of Chinese firms and the role of China in the developments of large infrastructures in Africa and highlight that the entry of Chinese companies in Africa's construction sector has intensified competition in the bidding process. Yet, China's investment in Africa is not growing at the same pace as other investments around the world under the Road and Belt Initiative (Chen, 2016). Even by Chinese standards, which are often presented as lower than those demanded by traditional donors, poor governance, corruption and the lack of a conducive business environment are becoming a strong constraint to investing in Africa (Ehizuelen, 2017).

In the last decade, there has been a proliferation of documents highlighting the infrastructure gap in Africa, and advocating for an increase of official development aid and mobilising private funding through PPP. In a collective study focused in twenty-four African countries financed by the World Bank and the *Agence Française de Développement*, Foster & Briceño-Garmendia (2010) provide a comprehensive diagnostic of different infrastructure sectors in the continent. For instance, they explain that, in 2008, the annual spending needs for the transport sector in Sub-Saharan Africa were estimated at $18.2 billion, of which $8.8 billion was required for capital expenditure and $ 9.4 billion for operation and maintenance. Despite a significant increase of aid to infrastructure development, there are doubts that the funding is sufficient (Gutman, Sy & Chattopadhyay, 2015). However, the availability of funding is not the only obstacle. A poor regulatory framework poses serious obstacles to attracting investment and means that many projects fail or are slow to materialise (Lakmeeharan, Manji, Nyairo & Poeltner, 2020). Osei-Kyei and Chan (2016) examine the adverse institutional context to develop

PPP projects in Sub-Saharan Africa, which is one of the developing regions with fewest transport PPP projects and highest number of failed ones.

The analysis of the study of African economic and political regimes shows how foreign power has controlled the development of the transport networks. During the colonial period, the network was designed according to external interests that have little to do with the needs of African societies (especially an extractive rationale, as opposed to the promotion of a local economy). As a result, responding to the achievement of the maximum network (or more efficient for the territory, and ultimately the logics of geography of power from the networks) in a way that was more consistent with pre-colonial societies was not possible anymore. After independence, the dominant groups replicated the same rentier practices within the borders of the new states, having also a significant impact on the transport network. From the 1980s, the economic crisis forced African states to rely mostly on international actors, which have a strong influence on how the network is shaped. In sum, it is observed that, in Africa, the ideal network is not necessarily the planned network, as the latter is the expression of external powers. After this review of the literature about the root causes that explain the rupture between the maximum network and the realised network, we need to explore other areas of knowledge that will help us to understand how the network has been executed.

Having seen this temporal framework and its discursive currents and economic phenomena occurring at the African level, we are interested in making it more concrete in the Cameroonian field of analysis and in the 1884-2020 period. We are interested in applying a reading of the geography of networks and power to better define these mechanisms.

2.2. Economic geography and its positioning with respect to transport infrastructure in Africa: the impact of the promotion of certain corridors

One of the first and more complete conceptualisations of the general spatial economic equilibrium was the central-place theory of Lösch (1954). Lösch's vision has been improved and completed but it remains highly influential. In 1991, Krugman developed the core-periphery model showing how economic integration may lead to an increase in the geographical concentration of industrial production via a self-reinforcing agglomeration process. These works were the kick-off for a new field of economic theory called the New Economic Geography (NEG), which intends to understand spatial agglomeration patterns of economic geography (Gaspar, 2021). Veltz (1996), using the French case, proposed an analysis of production networks that goes beyond the study of the costs of physical access and tries to understand the interaction of geography with technical factors, which have been rendered more complex by globalisation. Since the 1990s, two questions have greatly occupied the work of theorists: how to take into account imperfect competition and how to include transport costs (Fujita, Krugman and

Venables, 2001). In the last decades, the acceleration of the globalisation of the economy has fostered a growing interest in understanding how wealth is localised and why economic development concentrates the way it does, not only at international level but also within nations (Polèse, 2009).

In the era of information and communication technology, and when transport costs are falling, economic geography research shows the importance of proximity and the agglomeration of the economic sectors in clusters (Clark, Feldman, Gertler, 2001). A common goal of economic geographers is to obtain a better understanding of the spatial economic relations by introducing "strategic simplifications" (Krugman, 2003). The starting point is typically a theoretical spatial equilibrium model based on the assumption that people are homogeneous, behave rationally, competition is perfect and wealth is uniform across space. This principle is formalised in mathematical models that will then be the guide of empirical research. Despite the improvements that have followed, Krugman (2003) himself acknowledges limitations and difficulties to apply this model to the real world. Polèse (2009) underlines that empirical literature has had limited success to explain the regional variations in growth. He stresses, "even the most successful models seldom explain more than 50% of the observed variations over time (an R2 of 0.50 in regression models)". Therefore, it is important to remember that economic geography predictions may not be very accurate because they are based on simplifications.

In any case, economic geography has made valuable contributions to understand better the effects of space on the economy. Krugman argues that an important value of the new economic geography is that it has revealed that physical geography matters and it has somehow corroborated the classical models advocating for the self-organising character of spatial economy. It confirms the validity of authors like von Thünen (1826) on agricultural location, Weber (1909) on industrial location, and Christaller (1933), whose Central Place Theory explains that if there are several industries that differ in terms of scale economies and/or transport costs, the economy tends to develop a hierarchical structure. It is also in line with Lösch, in the sense that, in the evolution towards an equilibrium between cities, there should be some predictable regularities in spatial structure.

Economic geography is particularly relevant to understanding growth and poverty reduction in developing countries. A number of authors are concerned with the specific difficult situation of Africa and study the relationship between growth, trade, transport costs, infrastructure and natural geography. For Gallup, Sachs, & Mellinger (1999), the role of physical geography in Africa's development cannot be underestimated. Colonial powers were confronted with an unfavourable environment, which, to this day, has an effect on economic development. They also stress the correlation between a hot, extreme climate – humid or dry – and the low productivity of agriculture. Acemoglu, Johnson, & Robinson (2003) recall that deadly diseases such as malaria and yellow fever made many colonised areas off-limits to Europeans, a circumstance that affected the institutional development and that has subsequently constrained the economic progress. Although a rough relief of Africa is linked to higher investment costs in agriculture, construction and transport, historically, ruggedness has also been advantageous in protecting local populations from slave trade (Nunn & Puga, 2012).

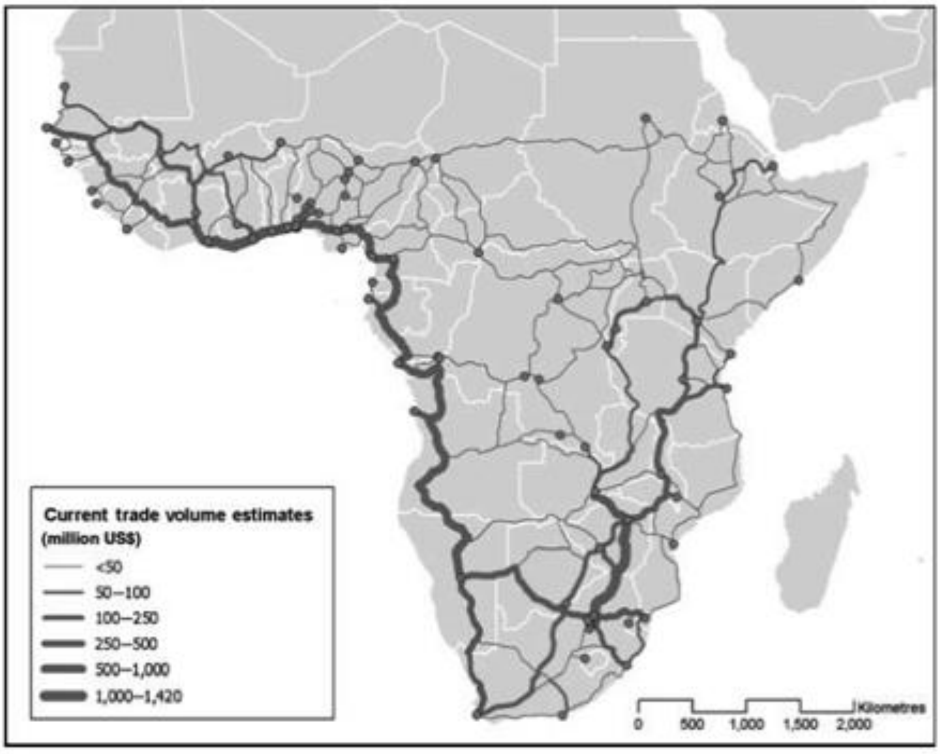
By analysing African trade flows, Limão & Venables (2001) quantify the dependence of transport costs on geography and infrastructure. They ask whether, in the context of globalisation (reduction of artificial trade barriers), transport costs are a higher barrier to trade than tariffs and show that poor infrastructure is very relevant in determining transport costs and reducing trade, especially for landlocked countries. According to Redding & Venables (2004), there are many potential reasons for the reluctance of firms to move production to low wage countries, including endowments, technology, institutional quality, and geographical location. Using basic gravity models of trade, they attempt to explain how geographical location affects per-capita income by focusing on two mechanisms. One is the distance of countries from the markets in which they sell output, and the other is distance from countries that supply manufactures and provide the capital equipment and intermediate goods required for production.

Coulibaly & Fontagné (2006) also address the weakness of South–South trade along three questions: What is the magnitude of untapped trade potential in the South? What responsibility does geography bear? Is the traditional gravity-type methodology a suitable econometric device to sort out these effects? Their paper assesses the importance of Sub-Saharan African countries' geographical and infrastructural disadvantages by focusing on the intra- and extra-regional trade flows of the West African Economic and Monetary Union and includes their trade flows with OECD countries. They conclude that the main determinant of limited intra-sub-Saharan trade is geography rather than the size of the exporting and importing economies. Bosker & Garretsen (2012) follow and adapt the empirical strategy introduced by Redding and Venables, which is firmly based in the theoretical NEG literature. They construct yearly measures of each Sub-Saharan country's market access over the period 1993–2009, making use of bilateral manufacturing export data involving at least one country. By using the constructed measures of market access, they conclude that there is a significant impact of market access on economic development, which is calculates as GDP per worker.

In 2009, Naudé reviewed the main findings of the abundant literature on economic geography in the African context and translated them into concrete actions to overcome the "proximity gap". His paper is therefore not empirical/analytical, but policy-oriented. This is relevant because most other NEG papers that address these issues in Africa conclude by stating some facts, but are rather neutral in proposing actions, if they propose any at all. Naudé proposes measures in the field of regional cooperation rather than regional integration. Regional cooperation suggests a broader agenda such as transport infrastructure and services (network effects, threshold effects, and compatibility requirements), trade facilitation (foreign aid, especially technical assistance and capacity building), decentralisation and local economic development (inequalities within countries; obstacles against domestic non-international transport), and migration (a redistribution of the African labour force would result in greater overall efficiency and compensate adverse geography).

Venables did a similar exercise in 2010. He attempted to understand how economic geography contributes to low performances of African economies by reviewing the contributions from a number of articles on the same subject, compiling the main conclusions and proposing a structured view of the problem. The author focuses on four issues. The first concerns the economic prospects of the private sector and the quality of the business environment. The second analysis is the public sector and the provision of key public goods. The third looks at African cities. In each of these cases, Venables argues that Africa's fragmented economic geography has led to low productivity due to the loss of economies of scale. The fourth issue regards the distribution of natural endowments.

The correlation between overland trade expansion and road infrastructure quality was studied by Buys, Deichmann & Wheeler in 2010 (figure 2.1). They use spatial network analysis methods and gravity-based trade modelling estimates to quantify trade growth as a result of upgrading the primary road network connecting major African cities. Calderón & Servén (2010 & 2014) address the link between economic development and infrastructure more comprehensively. Instead of trade, they correlate growth (GDP and other proxies) and inequalities with infrastructure, not only transport infrastructure, but electricity and telecommunications as well. In addition, infrastructure is measured qualitatively and quantitatively. Although this correlation may seem obvious and there is abundant theoretical work, empirical research is recent and few studies have tackled "inequality", in addition to the impact on "growth".



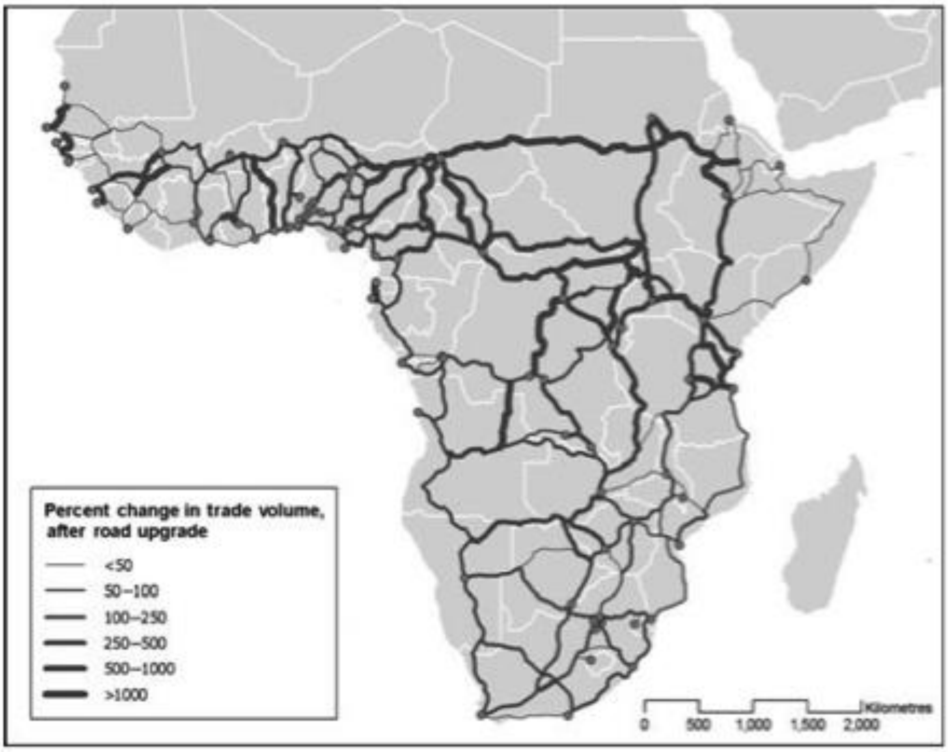


Figure 2.1. Trade estimates for the African road network (USD, million) and % changes in trade after road upgrading (Buys et al., 2010)

Some authors use these methods to analyse the territorial configuration and the urban system. Dorosh, Wang, You, and Schmidt (2011) confirm that agricultural production and travel time to urban markets are highly correlated in Sub-Saharan Africa, which means that both population and agricultural production follow a spatial concentric distribution encircling large cities. Lall, Schroeder & Schmidt (2014) study, for the case of Uganda, how policymaking should consider spatial efficiency–equity trade-offs in deciding the spatial allocation of infrastructure investment. Manufacturing firms gain from being in areas that offer a diverse mix of economic activities while public infrastructure investments in other locations are likely to attract fewer private investors. Storeygard (2016) establishes that the decentralisation of economic activity is related to road service level (paved or unpaved) around cities. These findings are consistent with Jedwab and Moradi (2016) who reveal that, despite significant road investments, urban systems have been stable in post-colonial Africa while complex hierarchized relations between localities have emerged. Gollin, Jedwab, & Vollrath (2016) conclude that the urbanisation patterns in Africa are mostly driven by the extraction of natural resources rather than by an industrialisation process. This singularity of the growth of cities in African resource-exporting countries probably entails a relationship between them and their area of economic influence that shapes a regional development different from the one favoured by cities in industrialised contexts.

Authors have been pleading the importance of helping African countries in market liberalisation and in improving their capacity to trade, claiming the fact that trade works as leverage for economic growth and poverty reduction (Stiglitz & Charlton, 2006; Collier

& Venables, 2007; Collier, 2007). The unquestionable proximity of most of these scholars with the World Bank and other development agencies has influenced policymaking in developing countries. Such is the case that, since the launch of the Aid for Trade initiative at the Hong Kong Ministerial Conference in 2005, trade facilitation and regional agreements are considered as central instruments for development assistance (World Bank, 2009a; African Development Bank Group, 2013; European Commission, 2011). Another prominent development policy document influenced by economic geography theorists is the World Development Report of 2009, entitled "Reshaping Economic Geography" (World Bank, 2009b). The main assumption is that, in a given territory or country, economic production cannot be encouraged simultaneously all over. It provides evidence that the geographic concentration of economic activity will increase the national average worker productivity and incomes. The emigration of workers and firms from low-density areas will ultimately also lead to higher per capita incomes in the regions that lose population. Transport infrastructure has a notable impact on location decisions and consequences on local and aggregate incomes. The report concludes that, although growth is necessarily unbalanced across space, development can still be inclusive, thanks to the convergence of living standards.

Directly derived from the economic geography discipline, the study of economic corridors is linked to the idea of concentrating investments where growth is most likely and relying on spill-over effects. In this respect, several authors look at the efficiency of the transport and logistics systems and the determinants of cost and prices. Teravaninthorn and Raballand (2009) explain why it is important to differentiate between transport prices and transport costs. High transport prices in Africa cannot merely be explained by lack of infrastructure in good conditions. Non-physical determinants, such as customs formalities, corruption and the prevalence of transport cartels, are still highly representative in the breakdown of transport prices. Even if costs are reduced, without an effective regulatory framework, there is no price reduction for the user and the profits are reaped by the transport cartels.

Arvis (2010) studies the case of landlocked countries and insists on understanding and addressing the political economic factors in both the landlocked countries and their transit neighbours. Rather than focusing only on the infrastructure, Arvis looks at the non-physical barriers to transport and supply chains. Linked to it, there are authors looking in more detail at the problem of the trucking industry and the overloading problem, which damages the roads and, in turn, has a direct consequence on the regulatory and market failures of the trucking industry. Overloaded heavy vehicles threatened road safety (especially if trucks are in poor condition) and led to increased vehicle operating costs (higher fuel consumption and premature breakdown) (Keita, 1989, Pinard 2010).

For Pedersen (2001), the worldwide containerisation and the concentration of the shipping industry had little immediate impact in the African transport configuration because of limited port capacity, predominance of unskilled low-wage professionals and deficient inland transport conditions. In Central and West Africa, the absence of a real regional integration still favours unfair competition between corridors and prevents the implementation of a coherent truck load-control policy (Zerelli & Cook, 2010; Bove *et al*, 2018). A study by Nathan Associates (2013) concludes that, for the case of Central and West Africa, inland transport accounts for 30 to 63 percent of financial logistics costs (depending on corridor and case study) and 19 to 50 percent of hidden logistics costs. This problematic situation contrasts with the improvements observed in Eastern Africa, particularly along the Northern Corridor from Mombasa to Kisangani (Kunaka, Raballand, & Fitzmaurice, 2016).

The study of economic geography became particularly relevant in the period between the late 1990s and the early 2000s, when the phenomenon of globalisation is consolidating. With Africa being one of the regions of the world with the highest transport costs, research work attempting to understand the growth-trade-transport nexus proliferated. These studies suggest theories that advocate a concentration of investment in the most productive areas and corridors, assuming that if wealth is generated in these areas, there will be spillover effects to poorer regions. This global trade paradigm has had a strong influence on the prioritisation of transport infrastructure in Africa, both ideologically and because of the strong dependence of states on the international finance institutions, such as the World Bank, which are strong advocates of the trade facilitation postulates. Therefore, this is a factor that in recent decades has potentially impacted the discrepancy between the maximum and the implemented network in Africa.

In this thesis, we believe that this view of economic geography can be enriched with a transversal view according to the evolutionary dynamics of networks and the correlation that they have with wealth generation. In Cameroon, we are interested in characterising the evolutionary phases of the network linking them to the generation of wealth and poverty in the context of rural-urban migration, extractive dynamics and the generation of economic activity in the large metropolises (Douala, Yaoundé and the Bamileké territory), as well as the urban agglomerations of the north connected to transnational trade.

2.3. Transport and urban geography in the developing world

From the point of view of economic geography, transport is mainly considered a "special commodity" (Sheppard, 2013) that is considered as part of trade costs incurred in selling products in distant locations. Under this approach, transport is "consumed" to provide access to places. The focus is put on market access and growth of locations. Differently, the foundations of transport geography lie on mobility, understood as the change of spatial location of people, goods and information to fulfil economic and social needs (Hoyle and Knowles, 1998). Mobility is contemplated in article 13 of The Universal Declaration of Human Rights. Transport enables mobility. Yet, physical and no-physical obstacles, what is called the friction of distance, restrict transport (Rodrigue, Comptois &

Slack, 2013). To satisfy the demand for mobility and reduce the impact of distance, transport systems tend to transform the environment and the spatial configuration of the territory, including demographic conditions. The understanding of the organisation of the space determined by the mutual influence between transport and economic and social activities is the object of transport geography. As Hoyle and Knowles explain, although economic sciences play "a leading role", "transport studies are essentially multidisciplinary", and geography, "as an integrative science", helps to structure and brings together the different fields concerned.

2.3.1. Transport development models

The theoretical frameworks of transport geography are closely linked to the study of the historical evolution of the territories and transport technology and engineering. The centre of interest is the link between transport and development. Development is understood in a comprehensive way, not only as economic growth, but integrating notions such as human development, equality, shared wealth, equitable territorial development, etc. Interestingly, several authors in this field have attempted to develop spatial models through the analysis of the historical evolution of transport networks in developing countries.

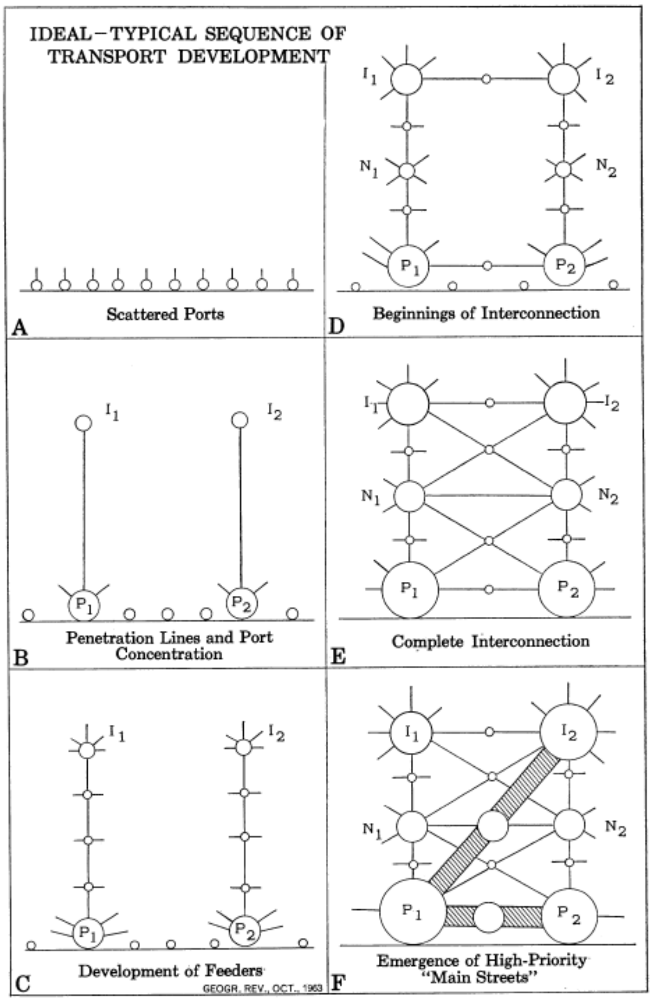


Figure 2.2. The Taaffe, Morrill and Gould model for developing countries (1963)

To characterise the full development of the transport network over the long term, the Taaffe, Morrill & Gould (1963) model represents its evolution in a hypothetical developing country from the pre-colonial situation to a fully integrated network that favours certain routes (figure 2.2). The initial phase of the Taaffe, Morrill & Gould model consists of scattered ports (A) that is followed by the emergence of some lines of penetration and the beginnings of concentration on a few ports (B). In the next phases, there is an emergence of feeder roads along the penetration lines (C), followed by some initial lateral interconnections (D). Secondary cities develop between the port and the line terminals. In the last phases, the interconnection continues (E) and ends by giving priority to some trunk lines or "main streets" between the largest urban centres (F). The Taaffe, Morrill & Gould model is based on the development of the transport network in Ghana and in Nigeria between 1920 and 1960.

Vance (1970) proposed a model based on the experience of countries such as the USA, Canada and Australia. It has five phases and combines the mercantilist model, as an economic practice, and the central-place model, as a spatial practice. The historical development of this model is obviously indicative of the phase of colonial exploitation of the world by Europe. Vance's model shows how transport systems were stimulated by mercantilism and how they, in turn, supported advanced urban systems with spillover effects on their peripheries.

Soja (1968) proposed a different approach to study the geography of "modernisation" in Africa. Based on his studies of Kenya, he stressed the behavioural components rather than the macro-geographical analysis of the development of the space-organising systems. All these models for developing countries were mainly based on the colonial period and in the situation during the years that followed independence. Rimmer did a step further in 1970 by proposing a transport network development model that integrated political, administrative and social considerations. In 1973, Hoyle adapted the model to East Africa including the pre-colonial context.

Francophone literature has significantly contributed to the study of the relationship between the transport networks, actors and the spatial organisation of the territories over time. Raffestin (1980) explains why circulation networks are an "instrument" of power par excellence. Networks are ideologically "read" at several levels: as they are drawn, as they are constructed and as they are used. Raffestin claims that ''every network is an image of the power of the dominant actor or actors". The transport network is a compromise between the maximum network and the means available and actual conditions. The maximum network is defined by the totality of the most direct relations, as if there were no constraints of any kind. The network is by definition mobile in the space-time frame. It depends on the actors who manage and control the network points, i.e., the relative position of each of them in relation to the flows that circulate or are communicated in the network.

Dupuy (1991) complemented this analysis. According to him, networks are generated by the existence of relationships between points, but the essential network characteristic is that the relationships are expressed through flows, whether of transport, information or energy. These are manifested materially through the physical infrastructures of the networks. In this way, a dialectic arises between the virtual network, the possibility of relations between actors, and the real network, the materialisation of relations between points. The network is precisely a dialectical articulation of the two sides of the same notion. The operator cannot avoid proceeding to a homogenisation of individual projects, and there is therefore a balance between the individual projects of connection and the organisational needs for the control of the network.

Debrie (2010) draws on historical geography or geohistory, a "hybrid" discipline championed by Grataloup (2009) that contributes to the identification of the long-term links between the temporal process of the progressive development of the transport network and territorial scales. Debrie summarises Raffestin's assumptions by proposing a template to help study how networks move from the project devised on paper to the actual physical network (figure 2.3.). A transport infrastructure network is the result of an economic, political and technical compromise that materialises in a specific space (territorial scales) and historical moment (temporal scales). For each timeframe and for each given delimited space, there are dominant actors around which these compromises are shaped. These powers manifest and develop their strategies in that space, where transport networks are built as a key instrument for the formation of territories.

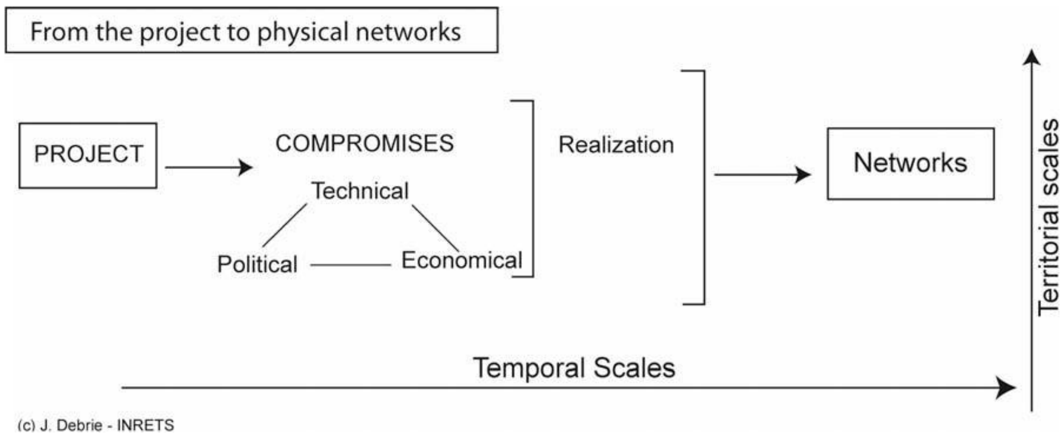


Figure 2.3. From the project to physical networks (Source: Debrie, 2010)

Debrie applies his template to the study of the land transport networks in West Africa over two periods of time, the colonial and the national era. In the colonial period, he identifies three developments within the colonial boundaries (figure 2.4):

1) An "economic structuring", where the control of the inland space and the export of agricultural products and raw materials dictated a network configuration based on penetration routes from the extraction and production areas to the seaports.

2) The lack of internal territorial or political structuring, which is evident when comparing the maps contained in the initial plans for structuring the colonies with the maps of what was finally constructed.

3) The initial distinction between coastal spaces (exploited areas with transport infrastructure and with economic returns on the short term) and the continental spaces (which were hardly exploited and which, at the time of independence, became landlocked countries).

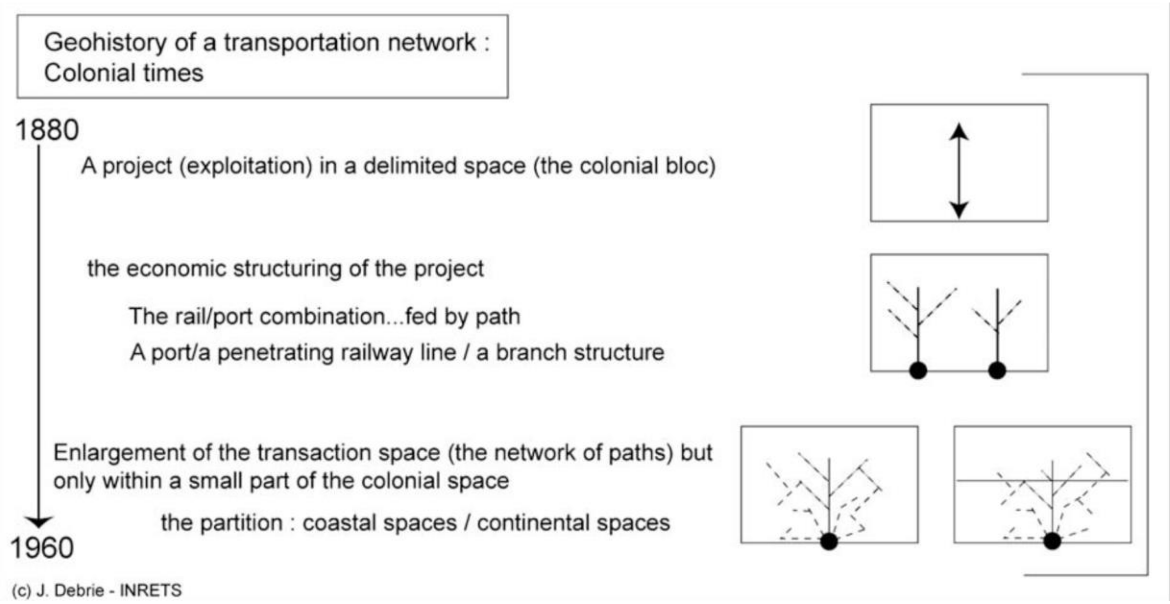


Figure 2.4. Geohistory of a transportation network: colonial times (Source: Debrie, 2010)

The result was a transport system that consisted in railway and port combinations, branches and "networks of paths".

In the national period, Debrie, for the continental (landlocked) states, identifies three processes within the boundaries of the newly created countries (figure 2.5):

1) The creation of an internal national road corridor to connect the capital with the rest of peripheral regions. In West Africa, he identifies that these links go in most of the cases eastwards and are given high symbolic political value.

2) The emergence of internal economic routes that link zones considered to be necessary for the national economy. These internal corridors were generally developed in the most densely populated areas with the highest agricultural production potential.

3) The development of external links to connect with neighbouring countries. This infrastructure was created mainly to allow the interior countries to have access to the sea. However, unlike in colonial times, and even though the extractive logic persisted, these connections are based on paved roads and not on railways.

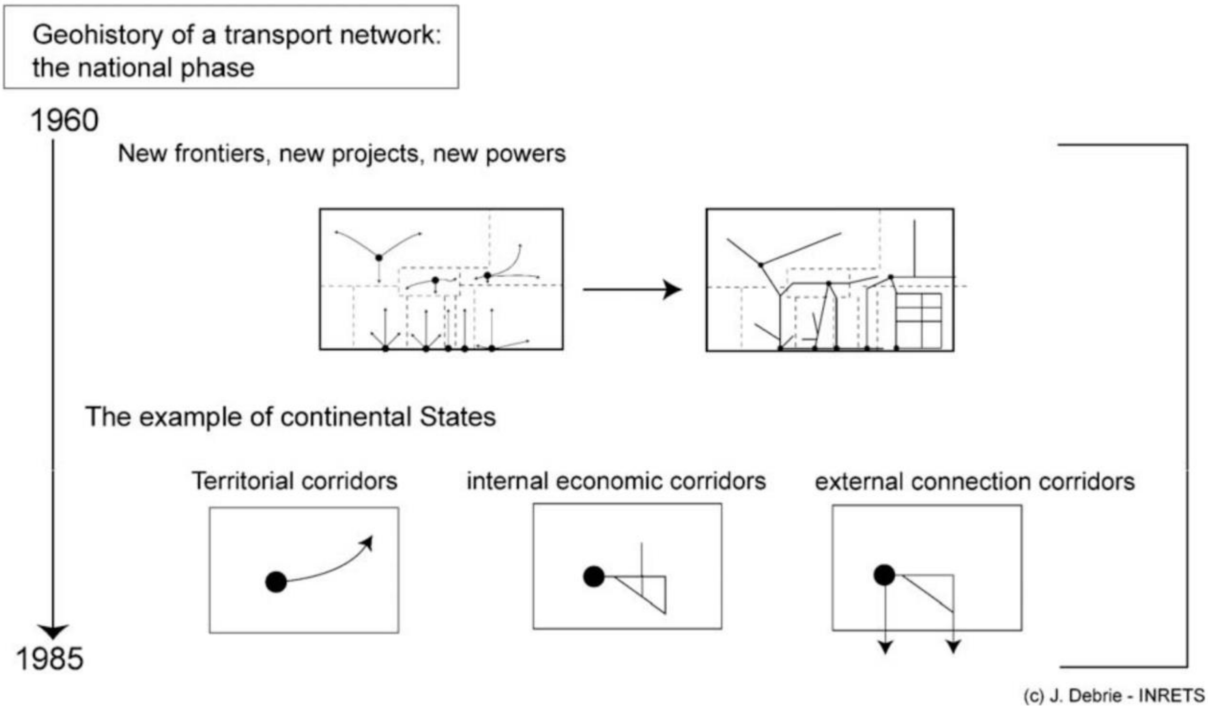


Figure 2.5. Geohistory of a transport network: the national phase (Source: Debrie, 2010)

The result of the national phase is therefore an embryonic international network, where the Taaffe, Morrill, and Gould's "High-Priority Main Streets" (phase F) emerge while internal and external interconnections (phase E) are not completed yet. Debrie concludes by emphasising the relevance of studying the evolution of the international transport networks as part of more recent efforts to promote regional integration, which are a response to pan-African ideals and to the need to overcome the small size of most of the African national economies. In this respect, he stresses out that the idea of compromise makes it necessary to consider regional projects that have not been realised in the colonial and national periods and questions whether a regional period has really begun.

In fact, this thesis is initially based on a reading of the relationship between transport and urban geography by applying the theories of Taaffe, Morrill and Gould (1963), Raffestin (1980), Dupuy (1985) and Debrie (2010), which will form the basis of our analysis of Cameroon's transport networks.

2.3.2. Quantitative transport geography

Having consolidated the contributions to transport development models applied to the African context, it is necessary to review the literature from the perspective of quantitative geography. As explained by contemporary authors specialised in the study of spatial networks (Gastner and Newman, 2006; Barthélemy, 2011; Ducruet and Lugo, 2013), since the 2000s, there has been a resurgence of the work started in the 60s and 70s by classic geographers such as Haggett, Chorley, Taaffe and Gauthier. In fact, at that time, the lack of data and appropriate computing capacities represented a major constraint to fully develop the theories and tools that had been proposed. Nowadays, the work has been revived, notably by physicists interested in all kinds of real-world complex networks, in particular, the so-called small-world networks (Watts and Strogatz, 1998). The small-world networks are, for instance, biological, technological or social networks that are "neither completely regular nor completely random". They are called "small-world" by analogy with the small-world condition characterised by the notion of the "six degrees of separation", whereby people are linked to one another by at most five links. However, transport networks, although also considered as complex networks, cannot be studied in the same way as most of the small-world networks because, being from the family of spatial networks, they are not scale-free and they are physically constrained (Barthélemy, 2022).

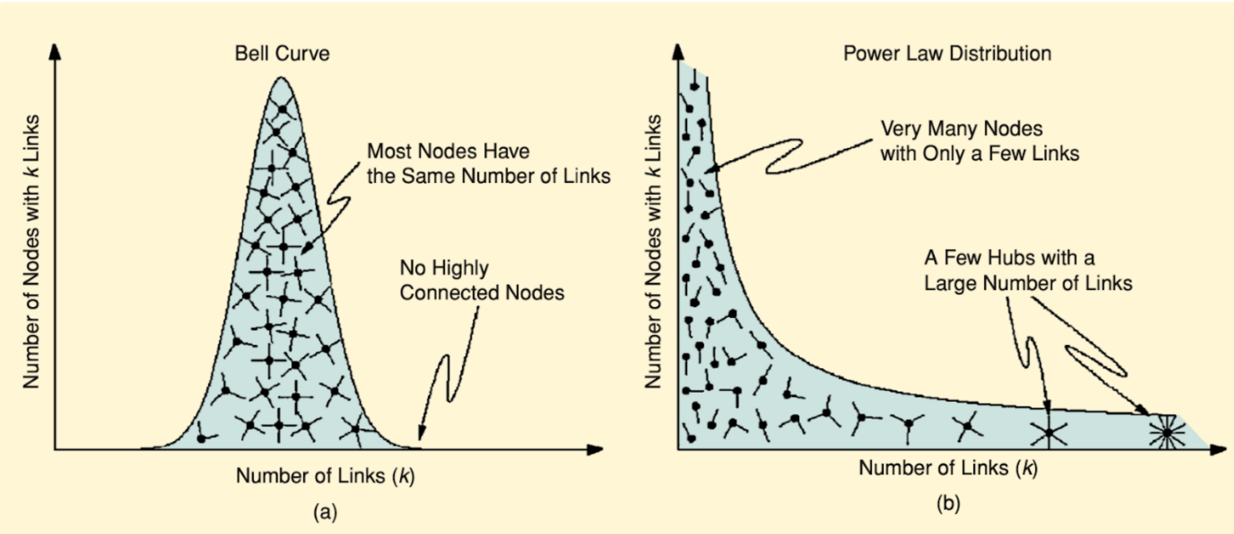


Figure 2.6. Different degree distribution of networks (Source: Barabási, 2003)

In figure 2.6, Barabási (2003) illustrates the different degree distributions of networks which, depending on whether they are scale-free or not, follow respectively a power-law distribution or a bell-shaped Poisson distribution. Csányi and Szendrői (2004) study the difference between fractal-scale networks and small-world networks. They explain that social networks, such as scientific collaboration networks and the internet, are typical examples of small-world networks. On the other hand, geographically constrained networks, such as the transport ones, are examples of networks with fractal scaling. Scale-free networks are characterised by a power-law degree distribution, where few nodes have many connections, acting as hubs, and most of the nodes have low connectivity. It would be the case of the air transport system. Differently, road and railway transport networks are planar networks (i.e. with no intersection between edges) where the nodes have a more homogeneous degree.

The fractal properties of transport networks offer a suitable perspective for studying their territorial expansion. Ildefons Cerdà, with his General Theory of Urbanisation of 1867, had already constructed a systemic and fractal epistemology *avant la lettre* through the instruments of homology and analogy, and later fractality and its interscalability, and combined them together, which provided him with a conceptual framework that allowed him to read and compare urban and territorial systems (Magrinyà, 2023). Modern literature in this field is based on Mandelbrot's postulates linking fractal patterns and geographical scales (Mandelbrot, 1982). Larrosa (2003a) explains that the fractal character of the transport network is based on the consideration that the model of territorial occupation is permanent despite the variation in scale. Territories of different dimensions can be compared if indices of a fractal nature are used since, by definition, they will be unaffected by scale. Different authors analyse the fractal nature of road networks and conclude that their shape and structure are both fundamentally irregular, scale-invariant and self-similar (Kalapala *et al.*, 2006; Zhang and Li, 2012). These properties were already identified by Christaller who, in his Central Place Theory (Christaller, 1933), observed how there is a hierarchical organisation of urban centres. By relating Christaller's centre-hierarchy spatial distribution of urban centres with the hierarchy of transport links, Czerkauer-Yamu and Frankhauser (2010) propose transport planning strategies at regional level based on a fractal and multi-scale approach.

Xie and Levison (2009a) differentiate five ways of studying the expansion of transport networks:

1. In the first place, the efficiency of the network by comparing the 'connectivity' and the 'shape' of the network can be analysed topologically. Transport networks can be simplified and represented as graphs from where basic properties can be identified. Garrison (1960), Bunge (1962), and Kansky (1963) conceived a series of measures of centrality, connectivity and shape, like the beta index or the diameter of a network. This structural analysis of transport networks based on graph theory measures was further developed by Taaffe and Gauthier (1973) and Dupuy (1985), among others. These measures include the gamma and alpha indices, indicating the degree of network connectivity and indicators of nodal accessibility based on the accessibility matrix and shortest-paths matrix. This type of analysis highlights the most favourable points of the territory from a network perspective.
2. The second stream of network growth analysis methods emerged from the 1970s and is based on transport demand forecasting models. Authors like Newell (1980), Sheffi (1985), Vaughan (1987) and de Dios Ortuzar and Willumsen (2011) propose transport engineering techniques that aim to optimise network design based on existing and future traffic flows. New investments to extend the network should be based on a balance between capital and maintenance costs, thus minimising the cost to the user, and maximising social and environmental benefits within budgetary constraints. However, these methods are considered to oversimplify the reality of transport flows, in particular regarding the factors driving future urban growth and how users will decide on their future mobility (Zhang and Levinson, 2005; Bertolini, 2007).
3. The third approach to studying the growth of transport networks integrates advanced statistical methods, which are made possible by the availability of

quality data and advances in computer technology, notably geographic information systems (GIS). Several research works based on multiple regression and simultaneous equations models establish correlations between transport provision and the socio-economic and demographic characteristics of the population (e.g. Mohammed, Shalaby & Miller, 2006; Cervero and Hansen, 2002; Levinson and Chen, 2005).

4. A fourth line of research recognises the complexity of transport networks and, while continuing to rely on the tools of quantitative geography, emphasises the political economy of the growth of the network. This economic literature looks at aspects such as pricing (Verhoef & Rouwendal, 2004), funding and asset management modes (Barankay, 2004; Kopp, 2006) and, in particular, for developing countries, the challenges and opportunities of road decentralisation (Humplick & Moini-Araghi, 1996a,b; Bardhan & Mookherjee, 2006). In addition, the study of the economics of network growth introduces key concepts such as network effects (Economides, 1996, Shapiro and Varian, 1998; Nakicenovic, 1998) and path dependency (Arthur, 1994; Liebowitz and Margolis, 1995; Pierson, 2000; Low, Gleeson and Rush, 2006; Dooms, Verbeke & Haezendonck, 2013). Because of the high investment costs in developing countries, infrastructure built in the past has significantly contributed to path dependency in the long term (Meacham, 2009; Jedwab, Kerby & Moradi, 2017; Poku-Boansi, 2020). However, the integration of these qualitative research methods into transport modelling remains a challenge. In particular, Kay (2005) warns of the limits of using the concept of "path dependency" to explain the absence of progress and of the difficulty of operationalising it empirically.
5. Finally, when the concepts of preferential attachment and self-organisation are borrowed from the natural sciences, many new opportunities open for a more realistic study of transport networks. There is an emergence of agent-based simulations that are grounded on the fact that transport networks are shaped by the behaviour of independent agents in the system (Barabási, 2003; Newman, 2003; Lam and Pochy, 1993; Helbing, Keltsch & Molnar, 1997; Yamins, Rasmussen & Fogel, 2003; Yerra and Levinson, 2005; Levinson and Yerra, 2006; Xie and Levison, 2009b; Barthelemy *et al*, 2013). For road networks, this implies a spontaneous hierarchisation of routes based on their use, as well as the degeneration and even abandonment of certain sections that are no longer used. The problem with these methods is that for the moment the simulations are based on simple human behaviour. The more one tries to approximate behaviours to reality, the more complex the models become. And finding the right balance is not obvious. On the other hand, many of the studies in this area are theoretical and have not been empirically validated, which casts doubt on whether their conclusions can be used directly for planning transport networks.

The Xie and Levison review (2009a) reveals that, since its recent emergence in the 2000s, the quantitative geography literature related to the study of transport networks has increasingly focused on the urban areas. Understandably, since most of these scholars are based in industrialised countries, their interest in applying the latest advances in network science to transport systems is to respond to problems of contexts where high levels of connectedness at national or regional level have already been achieved. The difficulty in the more developed regions of the world is related to road congestion in cities and the aim is to encourage public transport and other forms of mobility than the private car. Therefore, one aspect that researchers are primarily seeking to understand is urban street usage patterns in urban areas and the efficiency of the urban transport systems.

On the contrary, the study of topological network changes on a national or regional scale, which, as detailed by Xie and Levinson (2009) and Ducruet and Lugo (2013) produced many publications in the 1960s and 1970s, has received relatively less attention in recent decades. Most of the work that can be found in this field is related to nodal accessibility calculations and is policy oriented. Today, GIS software contains algorithms allowing it to calculate shortest paths, indices such as the Koenig number and the Shimbel index, and centrality measures such as the betweenness and closeness of the nodes. Several papers focus on the case of industrialised economies and are intended to serve as a planning tool for decision-making. It is, for example, the case of De Lannoy and Van Oudheusden (1991), who study the nodes in the Belgian road network, Murayama (1996), for the accessibility of the Japanese urban centres by railway, and Gutierrez and Urbano (1996), where the Shimbel index used to study how the trans-European road network has an impact on the accessibility of the European regions. In 2006, Chapelon calculated the topological accessibility driving from the European ports to population and regional economic poles. More recently, Weber (2016), used the classical graph theory indices to study the topological connectivity of the US urban freeway networks.

However, there is little literature that studies the development of networks in developing countries as proposed by Taaffe, Morrill and Gould in 1963. This was partly due to the lack of available information and computer tools. Now, it is possible to develop these methods taking advantage of technological progress. An example of this is the existing topological research that addresses the case of the expansion of the transport network in China. The work of Wang *et al.* (2009) analyses the development of the railway in China over one century using classical network connectivity and accessibility indices. Jin *et al.* (2010), examine the development level of transport infrastructure networks in the Chinese regions looking at indicators such as the infrastructure density, proximity and accessibility. The accessibility of the Chinese high-speed railway network is also analysed in terms of travel time to demonstrate that it not only improves accessibility but also increases inequalities within regions (Jiao *et al.*, 2014). Also, more recent publications study regions of India and are based on graph theory models that can be exploited using GIS software with network analysis functionalities (Daniel, Saravanan & Mathew, 2020; Daniel, Mathew & Saravanan, 2021). These examples in developing countries confirm the usefulness of classical theories of quantitative geography to determine the evolution of the efficiency of transport networks in countries with low infrastructure endowments such as those in Sub-Saharan Africa. These methods make it possible to characterise the network at given points in time and to analyse the evolution of the network for each period. In this way, the discrepancy between the planned network and the executed network can be determined.

A review of the literature on transport and urban geography reveals the resurgence of quantitative geography to study developing countries. Today, better computing tools are available, which we will apply to an evolutionary reading of Cameroon's transport network over a period of more than a century, which will enlighten us on the relationship between transport and geography.

2.3.3. Transport geography literature on Sub-Saharan Africa

In the context of Sub-Saharan Africa, transport geography is closer to political and social sciences than to quantitative work. Some authors have also addressed the influence of political regimes in the development of the transport networks. Colonial powers enforced bureaucratic obstacles to the development of local industries and controlled the economy by diverting trade through coastal cities, which was more favourable to the coloniser (Graham and Marvin, 2001). According to Péguy (1998), there was a polarisation effect, where a small number of urban centres and main corridors have a growing hegemony to the detriment of the rest of the country. Pedersen (2003) emphasises that these import-substitution policies allowed for a further progress of capital cities and main ports but did not contribute to the national economic integration or to the development of the national transport systems. This caused the decline of many pre-colonial prominent towns and accelerated the growth of others, particularly the ones that became colonial administrative centres (Njoh, 2006). Pirie (1982) describes how beyond the manifest positive effect and growth in some localities and central areas in Southern Africa, the railway network has been a factor of underdevelopment and a source of exclusion and poverty in the areas not served by it.

For Steck (2009), forced and violent expansion of the transport network through inland areas during colonial times cannot be considered as a development policy. The development of transport networks in Africa entailed the destruction of previous territorial configurations and the establishment of new spatial compositions. Slater (1975) described it as “a simultaneous process of internal disintegration and external reintegration”. For Debrie (2001), these mechanisms have led to territorial inversions. Centralities have changed due to physical and administrative discontinuities in the networks. Consequently, continental areas, such as the Sahel, which once were central to trade, are now considered landlocked. Conversely, coastal areas became central to trade because maritime transport was key to the expansion of the colonial empires. The colonial period was characterised by “the primacy of economic considerations and the absence of a political plan” Debrie (2010). Therefore, colonial territories had an uneven infrastructure provision, and the transport network covered only a limited space within the colonial boundaries. As we have seen, the existing transport discontinuities in distant regions were seen as administrative divisions of the colonial space, and when the independences were declared, some of these underserved areas delineated the national borders of the new states (Herbst, 2000).

The decolonisation led to the creation of fourteen, today sixteen, landlocked countries grouped in two areas: west-central (Mali, Burkina Faso, Niger, Chad, Central African Republic, South Sudan, Ethiopia, Uganda, Rwanda and Burundi) and south (Malawi, Zambia, Zimbabwe, Botswana) and Eswatini and Lesotho, which are landlocked inside South Africa. The artificial partition of the continent led to the breakdown of historical corridors that until colonial times were opening the hinterlands to the sea. In addition, the biggest coastal countries, like the two Congo, Cameroon, Angola, etc. have vast areas of their inland territory far away from the sea. Under pan-Africanist ideals, the notion of interconnecting African countries by road was introduced and generalised as soon as the colonial territories were broken down into independent states. The necessity of giving access to these new countries has encouraged until today a profuse literature about transport corridors. Already in the early 1970's, UNECA defined a network of roads linking all the capitals of the continent called the Trans-African Highways (TAH), which further supported the concept of corridors (figure 2.7).

When we look at works that illustrate the contemporary situation, it is relevant to mention Lombard & Ninot (2010) who explain that, after the independence, transport policies were not a break with the previous period but rather a continuation of the policies decided by the colonial powers. In the No. 20 of the open journal, EchoGéo called "Des mobilités aux transports. Regards croisés en Afrique de l'ouest" edited by Jean-Louis Chaléard in 2012, we can find useful contributions describing the situation in the 2000s such as Dagnogo, F., Ninot, O., & Chaléard, J. L. on the Abidjan-Niger railway and a study case on the Nouakchott-Nouadhibou road by Steck.

Transport geography literature on Sub-Saharan Africa is also interested in analysing accessibility, mobility needs and behaviours, and at capturing the social and cultural reality of the population. It complements disciplines like sociology and anthropology. Part of it is concerned with the vehicle motorization in Africa and the changes transport has brought in the social and economic relations over time. Chaléard & Chanson-Jabeur, edited, in 2006, a collective book about the railway in Africa where we can find contributions from different authors on a few existing lines around Africa, how they evolved since colonial times, the social role it plays and the challenges of privatisation in a context of structural adjustment policies. Gewald, Luning & Van Walraven (2009) edited a volume with contributions from historians, anthropologists and social and political scientists exploring aspects of the social history and anthropology of the automobile in Africa. Muñoz (2018), an anthropologist, shows, for the case of Cameroon, how the evolution of government policy and business regulation has translated into practice and describes how actors have contributed to the divergence between legislation and reality on the ground.

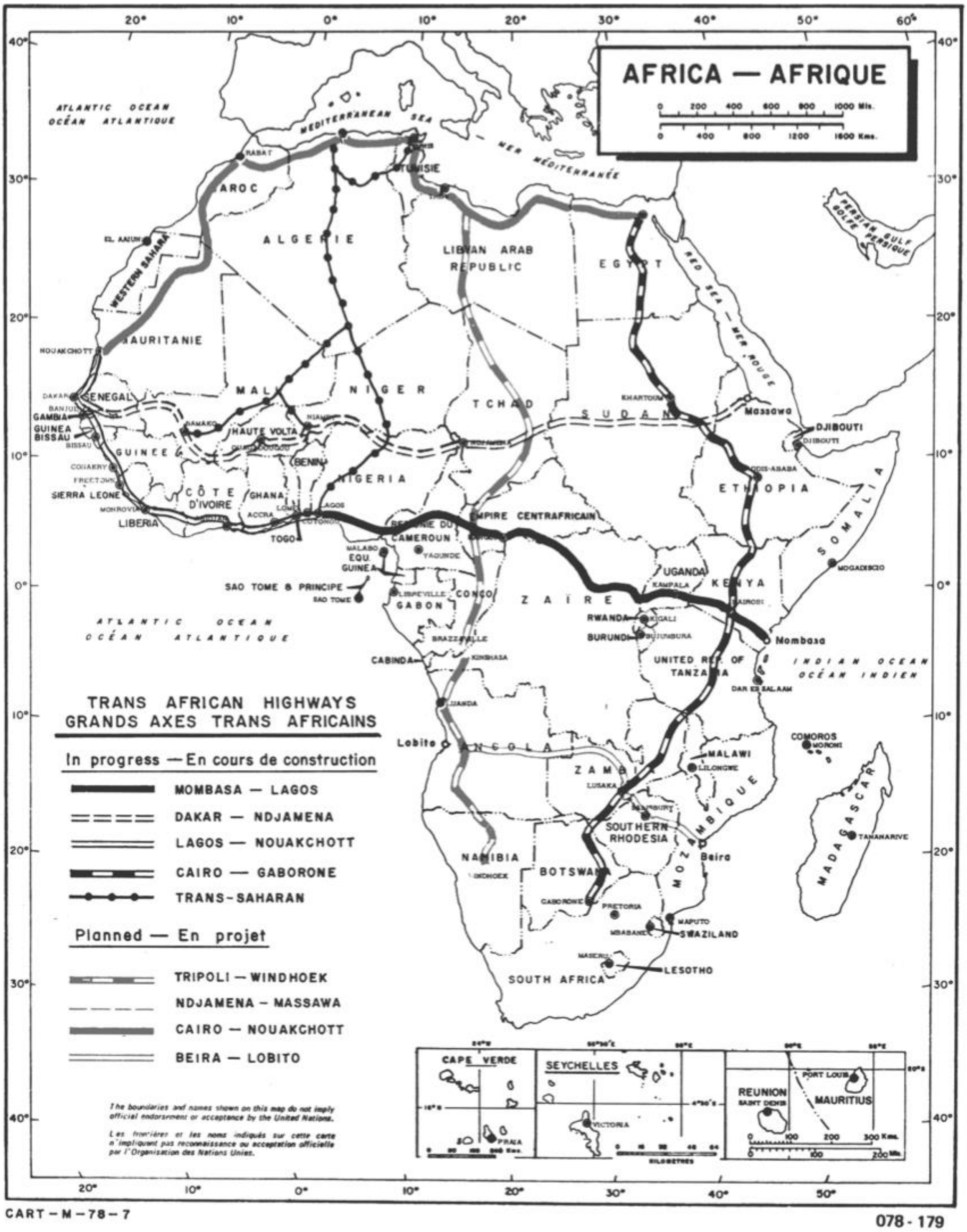


Figure 2.7. Trans-African highways as defined in 1978 (Source: Ousmane Gueye, Bangui Conference on Transport and Communications, UN Economic Commission for Africa 1978).

Other works are interested in understanding how mobility and accessibility affects the poor and vulnerable groups in African rural areas. Mwase (1989) discusses the political, social and developmental advantages of rural transport, but also its risks. For example, where cost savings are not passed on to rural businesses and producers, or its negative impacts like substitution of local goods by imports and increased migration. Acknowledging that good road quality does not necessarily translate into good transport services, Ellis & Hine (1998), produced a working paper for the Sub–Saharan Africa Transport Policy Program that describes the main features of transport service provision in rural areas in Africa and recommend policy measures. A significant number of authors have been interested in the correlation between rural mobility and poverty reduction. In 1983, Chambers described how governmental policies were neglecting remote and rural areas and the consequences of isolation on the impoverishment of the population. It is also worth mentioning the works of Leinbach (2000), Porter (2002 & 2014), Vasconcellos (2003), Bryceson *et al* (2003) and van de Walle (2009) and, for the case of Cameroon, Gachassin, Najman & Raballand (2010). These studies agree on the fact that it is difficult to estimate the impact of actions to improve rural accessibility, and they have in common that they look at the wider social benefits of an improved mobility, not only in terms of economic returns. Another characteristic is that they are interested in non-motorised means of transport, which play a fundamental role in the mobility of people with low income.

Given the high rates of urban growth in Africa and considering the role that urban centres play in shaping the territory, it is important to study the evolution of transport networks by looking at systems of cities. Godard (1996) warns of the criticality of the articulation between local and international transport and how urban efficiency impacts international competitiveness. According to Raffestin’s perspective on Christaller’s theory, in the developed economies, nodes were relatively more important than networks between the industrial revolution and 1950s (Raffestin, 1987). In this thesis, we have consulted some of the most relevant contributions to urban research in developing countries (Bairoch, 1985; Farvacque-Vitkovic & Godin, 1998; Stren & Halfani, 2001; Tacoli, 2002; Davis, 2006; Vernon-Henderson, 2002; Hardoy, Mitlin & Satterthwaite, 2013). Mobility in African urban areas can have a significant impact on the function of the inter-urban and international transport links. A good example of a comprehensive attempt to understand the political economy of urban mobility in Africa is the book written by Rizzo (2017) for the case of Dar es Salaam. Moreover, development aid agencies and programmes (World Bank, SSATP-Sub-Saharan Africa Transport Programme, GIZ-Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH…) and associations (CODATU-Cooperation for Urban Mobility in the Developing World, UITP-International Association of Public Transport…) have an important number of publications on urban mobility where the interrelationship between metropolitan mobility and international traffic are highlighted.

A review of the literature on transport geography in Sub-Saharan Africa shows that there is no comprehensive quantitative and transdisciplinary analysis that illuminates the economic and geographical theories of the impact of transport in developing countries. It is therefore pertinent to correlate geographical and economic developments and the evolution of land transport infrastructures from a multidisciplinary and quantitative perspective.

2.4. Economic impact of transport investments

To understand the rationale for the planning of transport networks by the authorities, it is important to review the literature that studies the relationship between transport investments, productivity and economic growth. In the Francophone literature, in 1974, Bonnafous & Plassard pointed out that the structuring effects (*effets structurants*) of transport supply were one of the main concerns of transport economics, as industrialised countries had eliminated major transport bottlenecks and could consider the use of new investments as one of the instruments of spatial planning. However, Offner (1993) evidenced the methodological deficiencies of the ex-ante studies used by decision-makers to justify major transport projects. He argued that a transport facility does not necessarily generate new economic value, but rather accelerates or consolidates the pre-existing dynamics and trends. For Steck (2009), the *effets structurants* theory is of particular interest in contexts where there are low levels of transport provision, like in Sub-Saharan Africa.

At the macroeconomic level, Anglophone authors are interested in the economic contributions of public infrastructure. Aschauer (1989), a precursor of these analytical studies, found that the productivity decline in the US in the 1970s was due to under-investment in public infrastructure. For Banister & Berechman (2003), the construction of a new transport infrastructure will only generate growth if there is a concomitance of mutually supported politico-institutional, economic and investment conditions. While Cost-Benefit Analysis (CBA) have remained the main tool to measure ex-ante or ex-post the economic impact of transport projects, in particular in developing countries (Little & Mirrlees, 1974; Squire & Van der Tak, 1975; World Bank, 2010…), economic benefits of transport projects are wider than time savings and reduced operating costs (Devarajan et al, 1997; Lakshmanan, 2011). In any case, the economic effects of new transport infrastructure are not obvious in industrialised countries, where networks are dense with high traffic flows, and decision-making based on econometric models remains controversial (Deng, 2013).

Throughout history, investment grants and subsidies to transport have been a common practice in search of economic returns. However, while in the developed economies public capital is injected from own resources and supported by private sector investments, in Sub-Saharan Africa, the economic push has traditionally been intended through development aid. Several prominent scholars have addressed the effectiveness of aid as a development instrument. Developmentalism economists like Rostow (1959) and Rosenstein-Rodan (1961) pleaded for massive foreign aid rather than relying on the scarce local savings and urged support for central governments with substantial international aid programmes to simultaneously stimulate investments in several economic sectors. On the contrary, Adler (1965) and Myint (1969) criticised international financial institutions' policies due to the lack of qualified human resources and institutional capacity of low-income countries to absorb large amounts of foreign aid. In 1977, Lipton and other development theorists warned of an "urban bias" in developing countries' governmental action. In their opinion, an economy based on heavy taxation of agricultural exports, that diverts resources to industry and urban development, is not viable and condemns rural populations to permanent poverty. In recent decades, development paradigms have evolved and as aid outcomes have not lived up to expectations, economists' positions for and against aid have often been at odds with each other. For instance, economists like Sachs (2006) and Collier (2007) believe that there are poverty traps from which countries cannot escape through free markets and democracy alone. Therefore, development aid is needed, to break a vicious circle. On the contrary, Easterly (2006) and Moyo (2009) consider that aid has the opposite effect to that intended. It disempowers people, corrupts institutions and generates an aid industry that lives off the fact that these countries do not emerge from poverty. Differently, Banerjee & Duflo (2011) argue that a more micro approach is needed to understand the real obstacles and motivations of people to improve their living conditions. To achieve this knowledge, they promote the use of randomised controlled trials in the social sciences.

Because aid has predominantly been channelled through projects, especially in the transport sector, their strengths and limits have been widely studied. Hirschman (1967) evaluated ex-post several World Bank infrastructure projects. He describes different sources of unpredictability, like technological problems or cultural or religious constraints, which challenge the performance of the project during its life. He also identifies the mechanisms that motivate key actors to engage in achievement-oriented behaviour and explains that, when the authorities commit themselves to a project, it is very difficult to back out. In 1986, Lecomte pointed out that a consequence of project-based aid is that projects seek short- and medium-term improvements but neglect the long term. Degeorges (1990) criticises the suboptimal way donors evaluate the projects they finance. Evaluations serve a strategy of self-legitimation, i.e., they help to create a screen between the international organisation and its external control bodies.

The impact of transport policies has been specifically analysed for the case of developing countries. These works attempt to go beyond classical cost-benefit analyses, which are based on traffic forecasting, and which cannot fully estimate some key direct or indirect impacts. Ali *et al.* (2015) propose new analytical tools to maximise the benefits (in agriculture) and reduce the negative externalities (deforestation and conflict-related impacts) of road improvements. However, in developing countries, policy formulation based on empirical evidence may even be more difficult due to lack of quality data (Berg, Deichmann, Liu, & Selod, 2017) and, in the case of Sub-Saharan Africa, to the existence of strong political-economy constraints (Beuran, Gachassin, & Raballand, 2015). Raballand, Macchi, & Petracco (2010) explain that transport-led growth misperceptions and political interferences are frequent. Blimpo, Harding, and Wantchekon (2013), in the case of Senegal, Benin, Ghana and Mali, and Burgess, Jedwab, Miguel, Morjaria, and Padró i Miquel (2015) for Kenya, provide some startling illustrations where the political utilisation of road investments has had a negative impact by marginalising parts of the population. Transport corridors' outcomes can be in the form of economic growth, social inclusion and equity (Roberts *et al*, 2020), but can also produce social trade-offs and have negative environmental impact (Laurance, Goosem & Laurance, 2009; Kleinschroth, 2016).

Despite their relatively low traffic, Sub-Saharan African roads have historically suffered from premature deterioration, which drastically reduces their expected economic returns. It is the result of extreme weather (tropical or Sahelian) combined with overloaded vehicles and lack of maintenance. In 1988, the World Bank published a detailed policy study on the causes and scope of this problem and on the possible options to overcome it (Harral and Faiz, 1988). Torres Martínez (2001) explained that structural adjustment programmes resulted in a substantial reduction in infrastructure capital spending, which contracted the already scarce resources allocated to road maintenance, and, consequently, roads in Africa entered an irremediable deterioration process. Since the 1980s, several research groups have been producing technical notes to improve road asset management in developing countries (the UK's Transport Research Laboratory-TRL, the US' Transportation Research Board-TRB, the French Laboratoire central des ponts et chausses-LCPC, the SITRASS network, etc.). Among the international organisations, the World Bank and the European Commission are the ones that have been particularly influential in showing the way forward to maintain the road network in Africa. In the context of the structural adjustment programmes, from the mid-1980s and during the 1990s, in view of the importance of transport to economic development, Transport Sector Projects (TSPs) were progressively introduced in Africa. A major reform was the introduction of second-generation Road Maintenance Funds (RMF), based on the idea that "commercialising" road management would secure and increase the efficiency in the use of the funds (Heggie, 1995). The main policies of the World Bank and the European Commission in support of transport sector development can be found in a selection of publications referenced in the bibliography (World Bank, 1996 and 2007; European Commission, 1991 and 2008; Runji, 2015).

The study of the economic impact of transport investments is very relevant when determining how the network deviates from its ideal configuration as it moves from the planned network to the executed network and, in turn, to the implemented network. The state-of-the-art reveals that transport investment decisions are largely driven by the hypothetical "structuring effects" of transport. While in developed economies, these effects are often the subject of controversy, as it is difficult to determine the impact of new infrastructure, in African countries the impact is significant as the networks are at a very early stage of development. However, African countries are also not exempt from political distortions or external interests, especially those of international donors. Consequently, the projects decided upon are not always those that have the greatest economic impact compared to the others. In addition, project implementation is often delayed for technical and administrative capacity reasons, thus reducing the expected returns. This slow development of the network is encumbered by the problem of lack of maintenance in Africa because the resources that the state can generate do not increase in direct correlation with the increase in infrastructure provision. Therefore, we can anticipate that the timing of the physical implementation of the transport infrastructure is key in determining whether the discrepancy with the ideal network widens when we would expect this gap to narrow. This is one of the aspects to be analysed in detail for the case of Cameroon.

The case of Cameroon will allow us to evaluate the role of infrastructure construction in the generation of wealth, while at the same time these new infrastructures generate maintenance needs that will require resources. One of the motivations for this thesis is also this balance between revenue generation and the construction and maintenance of transport infrastructures.

2.5. Transport in Cameroon

There are numerous historical sources describing the transport sector in Cameroon, dating back to the German colonial period. These sources are used and referenced in chapter 4 in which we take a geohistorical retrospective of transport infrastructure networks in Cameroon. During the French and British mandate and trusteeship, the colonial powers had to yearly report, first, to the League of Nations and then to the United Nations, about the development of the Cameroonian territories. These reports are a valuable source of information about the evolution of the transport infrastructure. Later, as an independent state, Cameroon has been heavily centralised and planning documents detail the investments realised over the years.

However, works specifically studying the history of the transport systems are limited and, at best, cover a specific period or location. Dikoume's PhD thesis (1982) is one of the few documents we have been able to find describing the development of the transport network in Cameroon throughout history, in this case from 1884 to 1975. However, beyond being a valuable source of information, the document is essentially descriptive in nature and the conclusions it proposes are more like those one would expect from a consultancy study on transport policy. Nkwi (2017) proposes a review of the role of river navigation during the colonial era (1916-1961), an aspect that is rarely addressed in the different works we have consulted. Despite the scarce navigability of rivers in Cameroon, water transport had a major economic importance in colonial times and greatly influenced the current territorial configuration as it determined where the first roads were built and was at the origin of population migration and the creation of towns where ports were built. The doctoral dissertation of Mi Wallang (1986) studies the utility of the cost-benefit analysis applied to road transport investments in the context of Cameroon. Although the tool had already been used by colonial powers, for example for the construction of the Wouri Bridge in 1952 in the city of Douala, its use became widespread in development aid programmes with the advent of independence. Mi Wallang focuses on urban transport investments, and he applies the cost-benefit analysis methodology to study the choices of transport projects in the city of Douala.

More recently, Mongo did a doctoral dissertation about the decision-making process in road infrastructure development in Cameroon since 1980 (Mongo, 2008). This thesis approaches the problem from the perspective of political science and the study of public administrations. In an exercise of analysis of the political economy of road construction in Cameroon, it contains relevant contributions on the relationship between good governance and different models of decision-making. In this sense, Harris's analysis is also insightful (Harris, 2011). He points to the weakness of the administration to explain the poor state of Cameroon's roads. It is not so much the lack of funds but the inability of the Ministry of Public Works to accomplish its contracting and supervision authority mission.

Some authors also analyse a historical period and contribute to the study of the transport sector through the analysis of the investments. Atangana's work about the FIDES Era (Atangana, 2009) is an essential reference for anyone studying infrastructure development in Cameroon. Indeed, between 1946 and 1957, two-thirds of the French investment in colonial Cameroon went to transport infrastructure and had a significant impact on how transport networks have developed until today. Hewitt (1979) discussed the impact of the aid provided by Europe under the European Development Fund (EDF) between 1957 and 1975. As he explains, during that period, 53% of the total EDF spending was allocated to transport infrastructure. The study of the EDF in Cameroon is therefore a good way to understand how the first transport investments were decided in the national period. Hewitt is quite critical of the extension of Trans-Cameroon railway between Yaoundé and Ngaoundéré, one of the rare rail investments in Africa built after independence. This rail line has been the object of numerous publications, which are also a rich source of information (Billard, 1966; Clarke, 1966; Okalla Bana, 2011). In particular, Muñoz (2022) details the political and administrative difficulties in carrying out the realignment of the former colonial Douala–Yaoundé line that took place during the 1970s.

As we have shown in section 2.1, where we have reviewed what the political systems literature has to say about the expansion of transport networks in Africa, the historical political science work specific to Cameroon also contains valuable information related to infrastructure investments. In this way, we have found relevant information in publications by Hugon (1968), Ngoh (1979), Njoh (1997 & 2017), Médard (1995), Owona (1996), Nzume (2004). The links between political science, geography and (road) transport are present in some relevant studies. Keutcheu (2010) explains that, given the insufficient development of information and communication technologies, the road network continues to play a key role in shaping public space (understood as the communicative and interactive dimension of a democracy). However, with many disparities in accessibility, with well-integrated and isolated areas, Cameroon is configured as an archipelago, limiting the sense of unity that the transport network could facilitate. A few other authors address the problem of isolation and absence of economic and political integration with the rest of the country due to the lack of infrastructure. Yemmafouo (2012) analyses the case of the Mamfé border region. He explains that this situation leads to a socio-economic reorganisation whereby the region will end up orienting its activities towards neighbouring Nigeria. Fofiri Nzossié, Temple & Ndamè (2011) study the impact of road infrastructure on the structuring and functioning of market spaces in North Cameroon.

Studying the evolution of urban systems is also a good way to understand the development of transport networks. In this sense, the work carried out by geographers of the *Office de la recherche scientifique et technique outre-mer* (ORSTOM) is a good source of information (Marguerat, 1973; Cotten & Marguerat, 1977; Champaud, 1983). These publications approach urban issues from multiple angles (demographic, migratory, social, administrative, economic, etc.). By cross-referencing this information, Marguerat proposed a hierarchy of cities and a representation of their networks of influence, which makes it possible to visualise the general urban organisation of the country in the studied period.

The maps in figure 2.8 represent the connections by symbolic axes, whose overall distribution draws a set of complex nodes, which are the strong points of the urban network. They show that twenty years after independence, two main networks were taking shape, around Yaoundé and Douala, with two secondary networks around Bafoussam and Bamenda and a Sahelian corridor along the Maroua-Ngaoundéré axis.

This concentration could have led to considerable discontinuities between the two metropolitan areas on the one hand and the other secondary cities on the other. However, recent studies show that Cameroon's urban system is now much more developed than that of most other African countries. Since the 1980s, the number and size of urban areas has increased steadily in the direction of a strengthening of all categories of city size. As a result, a real stratum of intermediate-sized towns has emerged, which play the role of real regional capitals (Gazel, Harre & Moriconi-Ebrard, 2010).

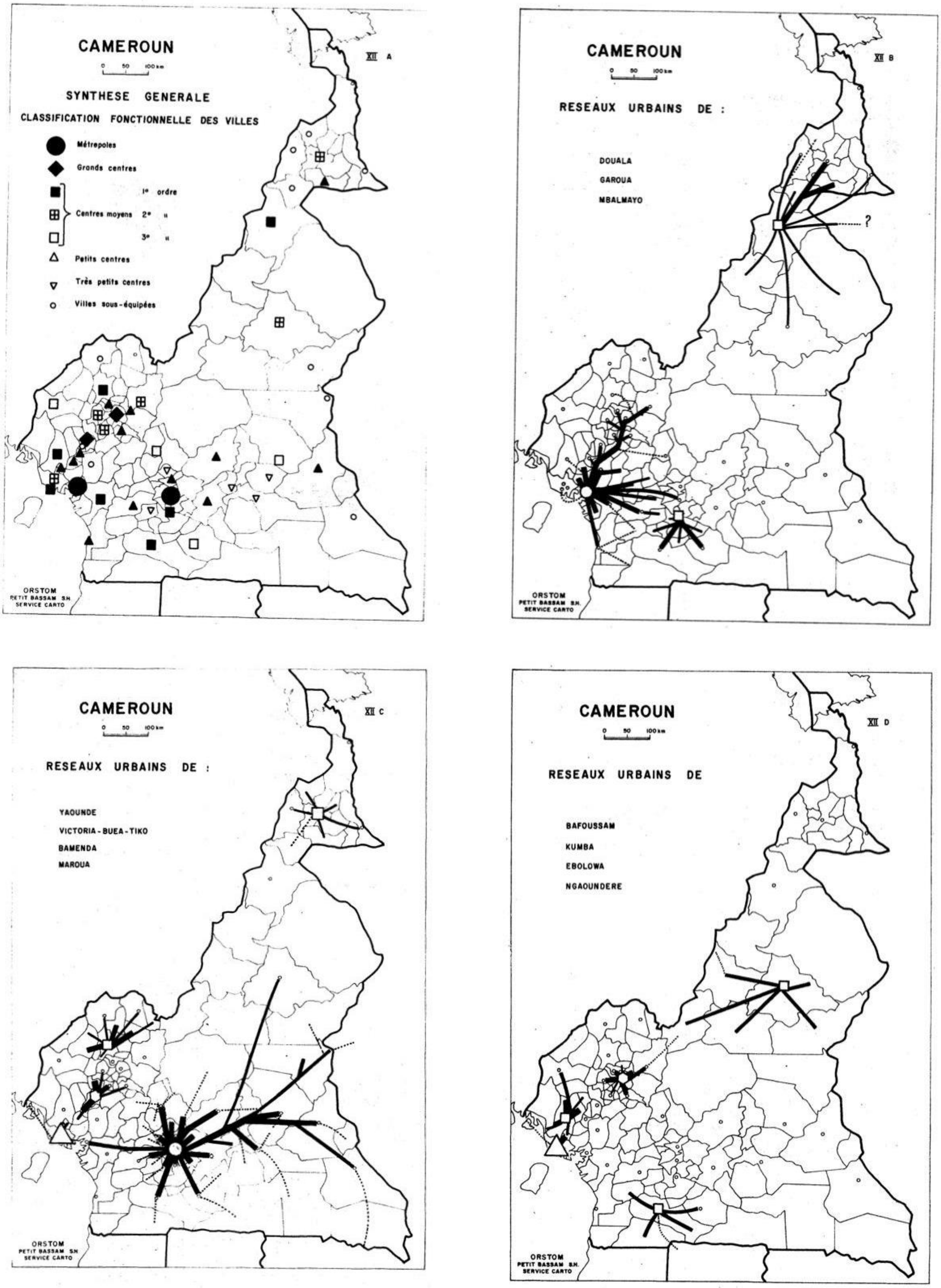


Figure 2.8. The forms of the urban network that associates and hierarchizes the cities (Source: Marguerat, 1973)

Transport in Cameroon has also been the subject of anthropological studies. Using a historical ethnographic approach, Nkwi (2011) is interested in the question of the mobility of the Kom ethnic group in the Anglophone Northwest of Cameroon. The study of how the introduction of roads and motor vehicles impacted the Kom's society brings useful insights of how the colonial transport network developed in the rural areas, beyond the main routes, between 1928 and 1998. Another ethnographic description with useful insights about the transport sector is the one done by Muñoz (2018) about the business sector in Ngaoundéré. Ngaoundéré is the terminus of the Trans-Cameroon railway, hence "a regional transport hub" where freight must be transferred to trucks and many business and administrative transactions occur. Muñoz socio-anthropological study of the business relations provides many elements that explain how the trucking industry operates in Cameroon and how it diverges to what official regulations stipulate.

In conclusion, it is noted that the existing literature with a historical perspective on transport in Cameroon is not extensive and we have not found any quantitative work on the geohistory of transport networks in Cameroon extending from colonial times to the present day. We mainly have to refer to other disciplines and indirect sources for references. These other disciplines are primarily related to the social and economic sciences. However, there is one aspect common to all of them, and that is to identify dysfunctionalities in the transport network and to associate them with certain decisions taken in a specific historical context. From the review of the literature, we also note the relevance of works that study transport at local scales, which not only complement the analysis at the national scale, but also allow the study of cross-border relations. These references underline the importance of studying the Cameroonian transport network in a regional context, including interconnections with neighbouring countries.

2.6. Conclusions from the state of the art

We began this thesis by asking ourselves what the main contributions to the study of the "infrastructure gap" in developing countries were, a concept introduced by Hilling in the 1970s (Hilling, 1970) but whose use became widespread during the 2010s, especially following the launch of the Addis Ababa Action Agenda in 2015. Although there is no clear definition of this concept, existing knowledge on transport networks in Africa shows that the shortcomings of transport networks are related to past decisions and that these are supported by different development paradigms (Slater, 1975; Hoyle & Smith, 1998; Steck, 2009; Debrie, 2010). It is these paradigms, spanning from the early stages of colonisation to the emergence of China as a dominant actor (Taylor & Zajontz, 2020), that determine network planning and thus where the deficit or gap lies. For this, the transport networks growth model proposed by Taaffe, Morrill & Gould (1963) offers a reading grid that can be combined with Raffestin's geographical theory relating networks and power (Raffestin, 1980), which postulates are applied by Debrie to the case of West Africa (Debrie, 2010).

The different disciplines analysed focus on certain aspects that help to explain the reasons for these gaps. The study of the consequences of the colonial occupation explains that the rentier policies have conditioned the configuration of the networks with an orientation from the mines and agricultural basins towards the export ports (Young, 1994; Clapham, 1996; Alesina, Easterly & Matuszeski, 2011). For its part, economic geography has a strong influence on the attempt to generate internal African markets where there is not yet sufficient trade (Naudé, 2009; Venables, 2010). Moreover, we note that transport geography and quantitative methods have great potential to explain this infrastructure gap (Xie and Levinson 2009a; Barthélemy, 2022). In particular, the fractal properties for the transport networks allow to study the growth of the networks in relation to the surface or population size of the territory (Larrosa 2003a, Czerkauer-Yamu and Frankhauser, 2010).

In recent decades, there has been a resurgence of quantitative geography especially in the study of urban mobility. However, despite some works on China (Wand *et al.*, 2009, Jin *et al.*, 2010) and India (Daniel, Mathew & Saravan, 2021), quantitative methods have not been sufficiently exploited for countries with incipient networks such as in Africa. Ultimately, the lack of good planning, which would approximate the planned network to the ideal network, leaves the final decision on the infrastructure to be implemented dependent on donor's agendas (Laïdi, 1989; Torres Martinez, 2001). International financiers use classical economic methods based on the economic and financial returns of the project (Little & Mirrlees, 1974; World Bank, 2010), but which do not consider the network as a whole (Lakshmanan, 2011; Roberts *et al.*, 2020).

The state-of-the-art reveals that understanding the relationship between transport and development in the African context has generated a particular interest among researchers. It highlights the difficulty of bringing together, contrasting and resituating this vast knowledge and, at the same time, finding realistic and practical conclusions to help promote greater efficiency in transport sector investments in sub-Saharan Africa. The poor reality of the transport systems shows that further research is needed but, probably, exploring other ways of how disciplines are interrelated and pairing them with operational experience to better guide and translate the findings into policy. Another challenge observed in the literature is the difficulty of inferring general conclusions about the African situation from case studies. Overarching studies, trying to find solutions to Africa as a whole, are as abundant as research at country or subnational level. However, extrapolations are not obvious. An evident reason is that Africa is a continent and realities are diverse. Another explanation may be that transport studies focus too much on the unique context of Africa, forgetting that, despite its uniqueness caused by geography and underdevelopment, there may be common features with the historical evolution of any country in the world, including industrialised ones. In addition, studies analysing the historical evolution of the transport network and linking it with the current problems seem limited or not sufficiently valued.

3. Research framework and methodology

3.1. Theoretical framework

As stated in the introduction, the objective of this doctoral thesis is to raise awareness among the current policymakers and implementing actors by identifying, and if possible, quantifying, the processes that contribute to exacerbating the transport infrastructure gap in Sub-Saharan Africa. The research question is to find out how, in Sub-Saharan African countries, the actual transport network distances itself over time from the maximum one, or in other words, whether the transport network adequately serves spatially the economic, political and social needs of the respective period.

The existing evidence that can be concluded from the state of the art confirms the proposition made in the introduction. In Sub-Saharan Africa, for specific temporal and territorial scales evolving over time, there are distinctive decision-making processes that derive from the power strategies of the dominant actors and that imply divergences between the ideal transport network and the one implemented. The decision-making processes are understood as a compromise between the territorial project and the technical, political and economic capacity to implement it, referred to by Raffestin (1980) and Debrie (2010). On this basis, we are in position to enunciate the **overall hypothesis** of this doctorate research:

The articulation between decision-making processes for network formation and the divergence between planned and implemented land transport networks in Sub-Saharan Africa can be characterised by cycles of growth and territorial scale increases, by the dialectic between networked economic development and development by networked territorial control, and by the hierarchical organisation of networks in response to lack of resources.

The state of the art provides the means to break down the overall hypothesis into **specific hypotheses** that allow us to operationalise the research. We need to develop a methodology allowing us to explain how the infrastructure gap is produced over time and to quantify it. Our conceptual framework is built on Taaffe, Morrill and Gould's (1963) network development model, Raffestin's (1980) networks perspective on the geography of power and Debrie's (2010) analysis of the spatiotemporal periods in continental West Africa. On this basis, one can identify successive historical periods or stages in the development of African transport networks, which they establish according to a distinctly colonial scheme, on a state scale after independence, and on a regional scale.

In our analysis, and for the territory of Cameroon, which can be extrapolated to Sub-Saharan Africa, we propose the following periods:

- the colonial period, with three approaches: German, French and British, and French after the Second World War,
- the post-independence years,
- the period of structural adjustment programmes,
- the period of regional economic integration.

During those different historical periods, the transport network has not developed linearly (and has done so with different spatial logics) and it is possible to determine phases in which it has expanded either at a faster or slower rate (some areas have been developed and not others) according to Taaffe, Morrill and Gould's model and Debrie's geohistorical stages. We can establish the level of network formation at each stage (in particular, through graph theory, assessing the dominance of connectedness or connectivity). In this sense, the state-of-the-art shows that, for each of the geohistorical periods, the transport network is the result of the combination of **three different dialectics** opposing:

- The rentier and extractive logics and urban development forces.
- The economic development and political control of the territory.
- An autarkic rationale and a more integrative approach on a regional scale.

Therefore, based on the historical periods defined above, on the identification of the three dialectics that shape the network, we can formulate specific hypotheses that will allow us to support the overall hypothesis of the research:

- **First specific hypothesis**: there is a characterisation of the cycles of growth and stagnation of the transport network defined by the different periods of colonial relations and political regimes.

- **Second specific hypothesis**: in each geohistorical period, the transport network develops according to a predominant trend in the dialectic between networked economic development (population) and development by networked territorial control (surface).

- **Third specific hypothesis**: the economic development goes through an iteration between economic growth of prioritised nodes and routes and impoverishment of territories and associated nodes.

- **Fourth specific hypothesis**: there is a hierarchical organisation of the transport network because of the lack of resources, which materialises in the prioritisation of the paving of certain roads of the main network. This discrepancy between the maximum and the actual transport network is the result of biased planning, funding decisions and the capacity to implement and maintain the network.

The studies in China and India show that quantitative geography is still today a relevant tool. However, despite its potential, it has not been sufficiently exploited in the case of developing countries, especially in African countries, where transport networks are still incipient. Modern GIS tools and the application of the theory of graphs allow integrating qualitative and historical research consideration into transport network analysis.

For the characterisation of the transport network according to the dialectic between networked economic development and development by networked territorial control, we will use the fractal theory. According to this tool, it is possible to determine, for each appropriate period and territorial scale, the predominant trend of network formation, according to the surface of the territory or the distribution of the population, which reflects the will of the groups in power.

3.1.1. Case study selection

The research will develop and evaluate in detail Raffestin and Debrie's theories in the case of Cameroon. Although Debrie's work focuses on the study of landlocked countries, the case of Cameroon is also relevant to illustrate how the network is the result of a compromise between a territorial project and the capacity to implement it. Cameroon's historical decision-making processes bring together appropriate elements that allow us to describe how the maximum network and the implemented network diverge over time. The choice of Cameroon as case study is justified for several reasons:

1. The pre-colonial history establishes two main settlements: in the north, along the fertile areas of Lake Chad, and one closer to the coast, in the Grassfields. The north was connected to the sea via the Niger River route (and thus through what was to become Nigeria). Although a great part of the trade was transported in caravans across the Sahara, exchanges between the Bamileke-Bamoun in south and the Fulani-Hausas in the north were frequent[5].

2. Cameroon has been subjected to the control of different colonising powers over time and in different territories: Germany, France and the United Kingdom (figure 3.1).

    - Until its partition after World War I, Cameroon could be considered as an entire colonial bloc as described by Debrie (2001).

    - Even after Germany's departure as a key player, neither the French nor the British Cameroons ever integrated the French bloc (French West Africa or French Equatorial Africa) or the British bloc (Nigeria). Two autonomous colonising rationales emerged, which implied two different strategies in the

[5] A typical example of these exchanges is the production of the Ndop fabric, a symbol of the Bamileke-Bamoun, which was spun from cotton from the north and dyed in the south (Awounang and Kouosseu, 2020).

British and French territories. These territories were not classified as colonies but as trusteeships.

- Within French territory, an attempt was made to connect the north with the coast, rather than via the Benue and Niger River route through Nigeria. At the same time, the territory of Cameroon acted as a link between the French West Africa and the French Equatorial Africa. This involved an investment effort on the French side that is not seen on the British side.

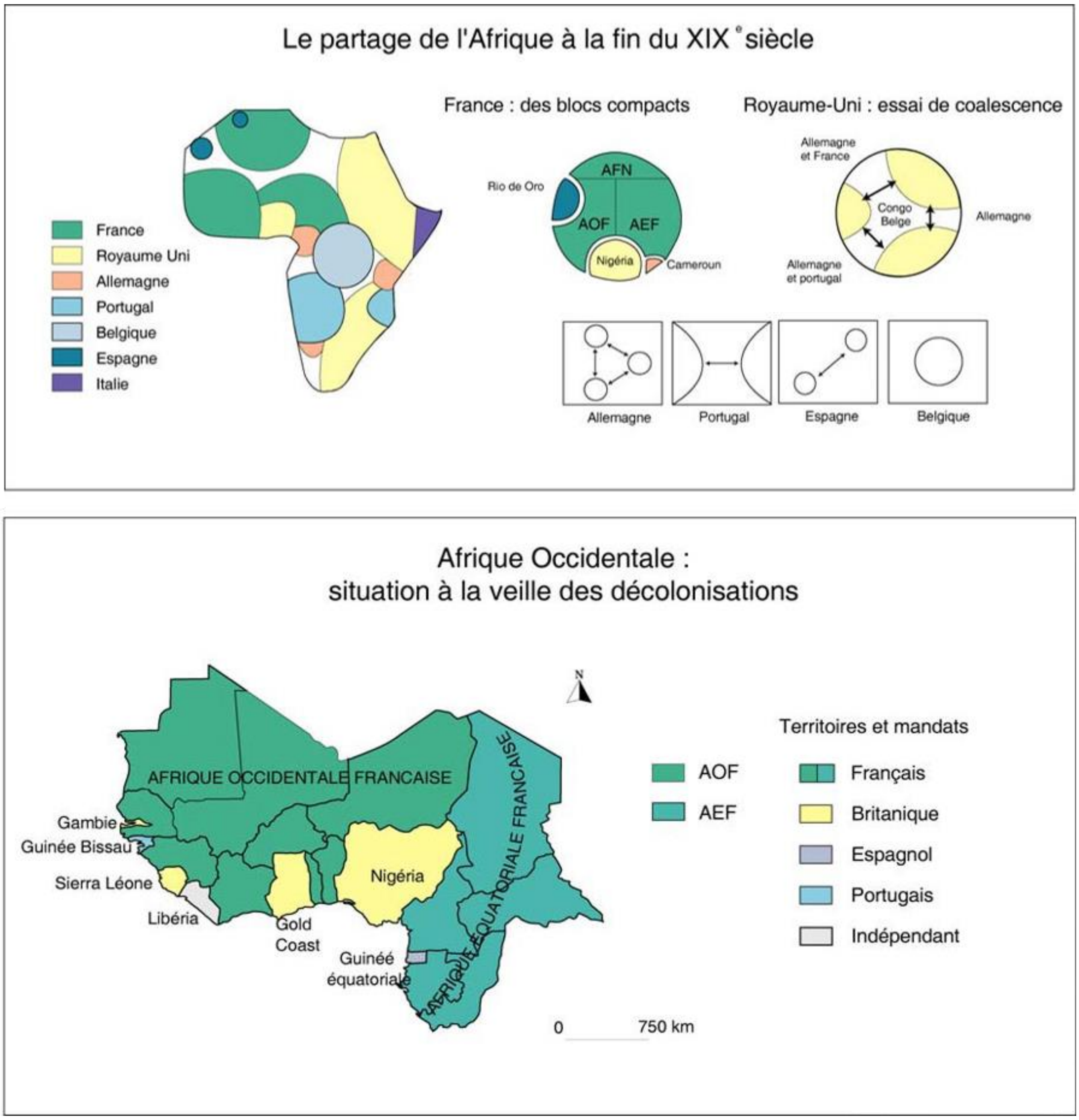


Figure 3.1. Cameroon's location in relation to the colonial blocs in Africa at the end of the XIX century and on the eve of independence (Source: Debrie, 2001)

3. With the dawn of independence and reunification between Francophone and Anglophone territories, a state model based on accessibility from the new capital (Yaoundé) was imposed. The new model resituated relations based on the existence of a fertile and already structured territory (the Bafoussam-Douala-Yaoundé triangle) and the need of the State to control its border crossing points and their access routes.

4. From 1985, in the context of the economic crisis and the structural adjustment programmes, the advent of greater donor power in the setting of investments implied, on the one hand, limiting the investment to the economic reality and, on the other hand, reinforcing international corridors.

5. The reality of the country's demographic evolution implies a strong rural-urban migration and a significant empowerment of the intermediary agglomerations in relation to the territory, as well as a geographical reversion at the level of poverty towards the north.

6. Although it is not a landlocked country like those studied by Debrie, in its northern part it behaves as such. In addition, it has both a coastal inland view and transnational connections to Chad, Central African Republic, Equatorial Guinea, Gabon, Republic of Congo and Nigeria. These countries are also connected to each other through Cameroon.

Cameroon has both a national and regional scale, as it acts as a hub for transnational communications, especially between the continental countries and their contact with the coastline. It is a territory whose surface has essentially a continuity over time despite the variations of the colonial period.

We can therefore conclude that a remarkable aspect of Cameroon is that the territorial scales of the colonial bloc, whether unified or partitioned, and of the independent state are very similar. This fact will facilitate our research work since, for the purposes of studying the transport network, the changes in the perimeter of the territory over time have little impact on it. Moreover, in this part of Central Africa, Cameroon has a maximum centrality, so the study of its territory will allow us to draw conclusions on a regional scale.

3.1.2. Methodology and logical validation framework

Overall, the methodology aims to establish how much the maximum network differs from the executed network, which gives an indication of the existing efficiency. In addition, although the concern to reduce the deficit of transport infrastructure investments in Africa is recurrent in most of the literature consulted, the cost of the protection and maintenance of existing roads in relation to the overall investments is rarely adequately considered. In Cameroon's case, we can make these relationships between geography, power and transport networks explicit. For this purpose, we have developed the methodology following six approaches:

A. Geohistorical study of the transport infrastructure network in Cameroon

Through a description of the development of the network, this part of the research will raise the question of what the main phases of the geohistorical processes are, from the maximum network to the real network. First, the thesis wil establish the stages of evolution of the transport network in Cameroon based on an application of the 1963 Taaffe, Morrill, and Gould's general model for transport networks in developing countries. To this end, several strategic documents throughout the period 1886-2015 will be collected and analysed. Thanks to the historical and cartographic resources available, we will characterise the transport infrastructure and we will study the correspondence between the different stages of development of the network and the main political and economic events that marked the country's history.

B. Topological analysis of the network

In the consolidated stages of the network (1930-2015), the thesis will analyse the correlation between topological indicators and the phases of network evolution. For this purpose, it will use different network analysis tools:

B.1. Shortest-paths analysis: in particular, we will calculate the detour index, which is a suitable indicator to show the difference between the ideal network and the network travelled.

B.2. Alpha, gamma and GTP indices to characterise the evolutionary periods.

B.3. Betweenness and closeness indicators to establish the evolution of the most central nodes and validate the change of institutional power strategies.

C. Analysis of infrastructure provision according to territorial and population distribution

We will differentiate three classes of land transport infrastructure:

- paved/asphalt roads,
- gravel roads and
- railways.

The distribution of asphalt roads will be the subject of specific analysis as a differentiating criterion for the networks. The methodology used will determine the following:

C.1. Population density and evolution of the distribution of investment in networks per inhabitant and per surface area.

C.2. Fractal index as an indicator of infrastructure provision and to establish the weight of population and surface area criteria in network planning. We will identify the moment of change from a rationale of economic returns associated with the population to a logic of territorial control.

C.3. Geographical evolution of poverty and the correlation with transport infrastructure provision (fractal index).

D. *Assessment of the role of urban centres and their accessibility in the expansion of the overall network*

In addition to analysing the density and infrastructure provision of departments and regions, it is relevant to study the urban centres and how their population has evolved. We will see which localities have grown the most and those that have fallen into decline and analyse their position in relation to the network. This analysis will allow us to better characterise Cameroon's urban systems and to determine their coherence with the evolution of the transport network. In the final analysis, we intend to assess the predominant role of the logic of territorial control versus the pre-eminence of urban centres and their access networks.

A 2-hour access index to the major urban centres will be calculated over time. It represents the total distance that can be travelled from those centres within a limit of two hours. This indicator shows whether the access network to a city has improved over the years or, on the contrary, it has contracted. In addition to the number of links, the condition of the asphalted roads surrounding the cities is key to determining travel time and, therefore, in increasing or reducing the 2-hour access over time. It is a good indicator of the different investments needed around the urban centres to adapt their networks.

E. *Evaluation of transport investment expenditure over time*

We will estimate the availability of public resources for transport investments and the actual infrastructure expenditure carried out. The correspondence between the availability of resources and the resources devoted to transport infrastructure will allow us to establish whether there is a correspondence between desires and reality.

F. *Costing of road asset management*

This part of the research focuses on the period between 1995 and 2015, where reliable data about the budget allocated to road maintenance and vehicle load management is available. We first calculate the budgetary allocations to road maintenance in Cameroon and compare it with the estimated needs. Then, we appraise the strength of the vehicle load management policies in Cameroon, and in particular the cost-effectiveness of installing and operating weighing stations in the Douala-N'Djamena corridor.

Table 3.1 consolidates and summarises the conclusions of the state of the art, the theoretical framework and the methodology proposed for this research:

	Research stage	Validation procedure
Research objective	To raise awareness among current decision-makers of the long-term consequences of measures taken to expand the transport networks in Sub-Saharan Africa and provide tools to improve their efficiency and sustainability.	--
Research question	In Sub-Saharan African countries, over time, how close is the ideal transport network to the actual network? Is the transport network adequately spatially serving the economic, political and social needs of the corresponding period?	--
State-of-the-art evidence	In Sub-Saharan Africa, for specific temporal and territorial scales, there are decision-making processes that derive from the strategies of power of the dominant actors, and which imply divergences between the maximum and the executed transport network.	Literature review
Overall hypothesis	The articulation between decision-making processes for network formation and the divergence between planned and implemented land transport networks in Sub-Saharan Africa can be characterised by cycles of growth and territorial scale increases, by the dialectic between networked economic development and development by networked territorial control, and by the hierarchical organisation of networks in response to lack of resources.	Corroboration of the four specific hypothesis
Specific hypothesis 1	There is a characterisation of the cycles of growth and stagnation of the transport network defined by the different periods of colonial relations and political regimes.	A. Geohistorical study of the transport infrastructure network in Cameroon B. Topological analysis of the network

Specific hypothesis 2	In each geohistorical period, the transport network develops according to a predominant trend in the dialectic between networked economic development (population) and development by networked territorial control (surface).	C. Analysis of infrastructure provision according to territorial and population distribution
Specific hypothesis 3	The economic development goes through an iteration between economic growth of prioritised nodes and routes and impoverishment of territories and associated nodes.	D. Assessment of the role of urban centres and their accessibility in the expansion of the overall network
Specific hypothesis 4	There is a hierarchical organisation of the transport network because of the lack of resources, which materialises in the prioritisation of the paving of certain roads of the main network. This discrepancy between the maximum and the actual transport network is the result of biased planning, funding decisions and the capacity to implement and maintain the network.	E. Evaluation of transport investment expenditure over time F. Costing of road asset management

Table 3.1. Logical validation framework of the doctoral research

The four specific hypotheses will be corroborated for the case of Cameroon. They have a logical order that sets the methodology of the research that will be developed in the following chapters. They will contribute to validate our overall hypothesis. The first hypothesis will be supported by putting together historical sources and digitised maps that will be analysed with topological tools (chapters 4 and 5). These initial results will take the form of a timetable characterising the transport network in its political and economic context. The second and third hypotheses will be tested according to the extent to which networks are developed, considering the demographic and urban characteristics of the country (chapter 6). Taking advantage of the fractal characteristics of transport networks in the territory, and assuming Raffestin's theories linking networks and power, we will correlate the expansion of the network with the policies of occupation of the new territory and control of the population. Finally, to measure the fourth hypothesis we need to look at the match between desires and the actual capacity to implement and maintain the network over time (chapters 7). In this part of the research, we will look at the actual capacity to materialise the planned network in concrete projects and to ensure its durability. As indicated by the blue arrows, although each hypothesis has its own privileged validation methods, these also serve to validate the other specific hypotheses.

As in the case of Debrie (2010), this research focuses on the study of physical networks. Although it integrates other elements, such as the analysis of transport organisation, the role of the different operators and modal split, the doctoral dissertation focuses on road and rail infrastructure rather than services. Nor does it cover port or maritime aspects or domestic air transport within the country. This delimitation of the perimeter of the research is intentional and is justified to avoid trying to cover too much information and end up losing the objective of the research, which is the study of the relationship between geography, infrastructure networks and power.

3.2. Tools and methods

As we have explained in the introduction, this thesis uses the case study as a general research method. Based on the conclusions of the state of the art and the hypotheses put forward, we intend to operationalise the research in the following way:

1) Constructing a methodology that links the evolution of a territory and the evolution of the infrastructure with transversal and multidisciplinary methodologies using geohistorical analysis, graph theory, fractal theory, cost-benefit analysis and the geographical theory of power from networks.

2) Establishing instruments for evaluation of:

    a) The dialectic between the networked territorial control (surface predominance) and the networked economic development (predominance of nodes and corridors following the logic of Taaffe and Debrie).

    b) Scale variation cycles (local, national, regional) characterised by growth and stagnation (evolutionary network techniques).

Referring to figure 1.1, this thesis aims to rely on two principles to account for changes in scale and thus allow for its generalisation. First, it is a case of replication, because what we are going to do is to replicate the models of Taaffe, Morrill and Gould and Debrie for the case of Cameroon. Secondly, we rely on deductive theory, by which we establish tools to assess, on the one hand, the territorial dialectics of the network between territorial control and economic development and, on the other hand, the temporal cycles and the variation between local, national and regional scales. The different research tools used in this thesis are detailed in the following sections.

3.2.1. Geohistorical review of the transport network in Cameroon

The approach used for the understanding of the evolution of the transport network in Cameroon is based on geohistory, a "hybrid" discipline where the "domains of validity" are "region-periods" (Grataloup, 2009). Debrie (2010) explains that geohistory allows the study of the dynamic relationships between territorial scales, power and transport networks over time. We will reconstruct these past links based on documents and evidence (material and oral) that will be critically analysed and, where possible, georeferenced with the intention to describe and explain the process leading up to the present situation of the network.

Historical written primary sources are government documents, reports and newspaper articles that are referenced in footnotes, notably in chapter 4. Examples include, from colonial times, the Annual Reports of the French and UK Governments to the General Assembly of the United Nations on the Cameroonian territories administered by them. From the national period, it is worth mentioning the Five-Year Economic Development Plans. On the other hand, secondary sources are indicated in the main text, following the citation, with the name of the author and the year. The full reference is provided at the end of the document in the bibliography chapter. Secondary sources are mainly books and articles of authors addressing different topics, for instance, about public investments in specific periods such as Bobrie (1976), Dupré la Tour (1998) and Atangana (2009).

3.2.2. Mapping of the network - Cartographic data

The mapping will be carried out for land transport networks, i.e., roads and railways. While this research examines the choices made since the initial years of the German colonisation, the quantitative spatial and territorial analysis only starts in 1930, shortly after the commissioning of the Yaoundé-Douala railway and at the end of the construction of the Yaoundé-Garoua Road connecting the south and the north. Waterways are not included because they fell into rapid disuse from the 1930s onwards, particularly with the advent of road transport. Before that date, the transport system in Cameroon could hardly be considered as a network, as it consisted of three isolated small systems (one in the north, one in the east and the main one close to the coast) and a few penetration lines with short sections suitable for motor vehicles. However, as we will see, those initial choices were determinant in the subsequent development of the network. Likewise, throughout history, there are other key moments that need to be identified and characterised to understand how the network works, why it has reached this situation and, in this way, offer elements to improve future decision making on the transport network.

We have mapped the road network for seven different years: 1930, 1955, 1966, 1978, 1995, 2005, 2015. We have chosen years where data was available and significant infrastructural changes were observed compared to the previous period, trying to keep the intervals between 10 and 15 years. As we have explained above, the first map is of 1930, as it is from that year that the transport system in Cameroon can be considered as a network that connects by road the different regions of the country, in particular the south and the north. The maps are based on the classified network existing in 2015 obtained from the Ministry of Public Works[6]. Six of the maps are in figure 3.2.

[6] Ministère des Travaux publics (MINTP). (2015), Référentiel Géographique Routier du Cameroun

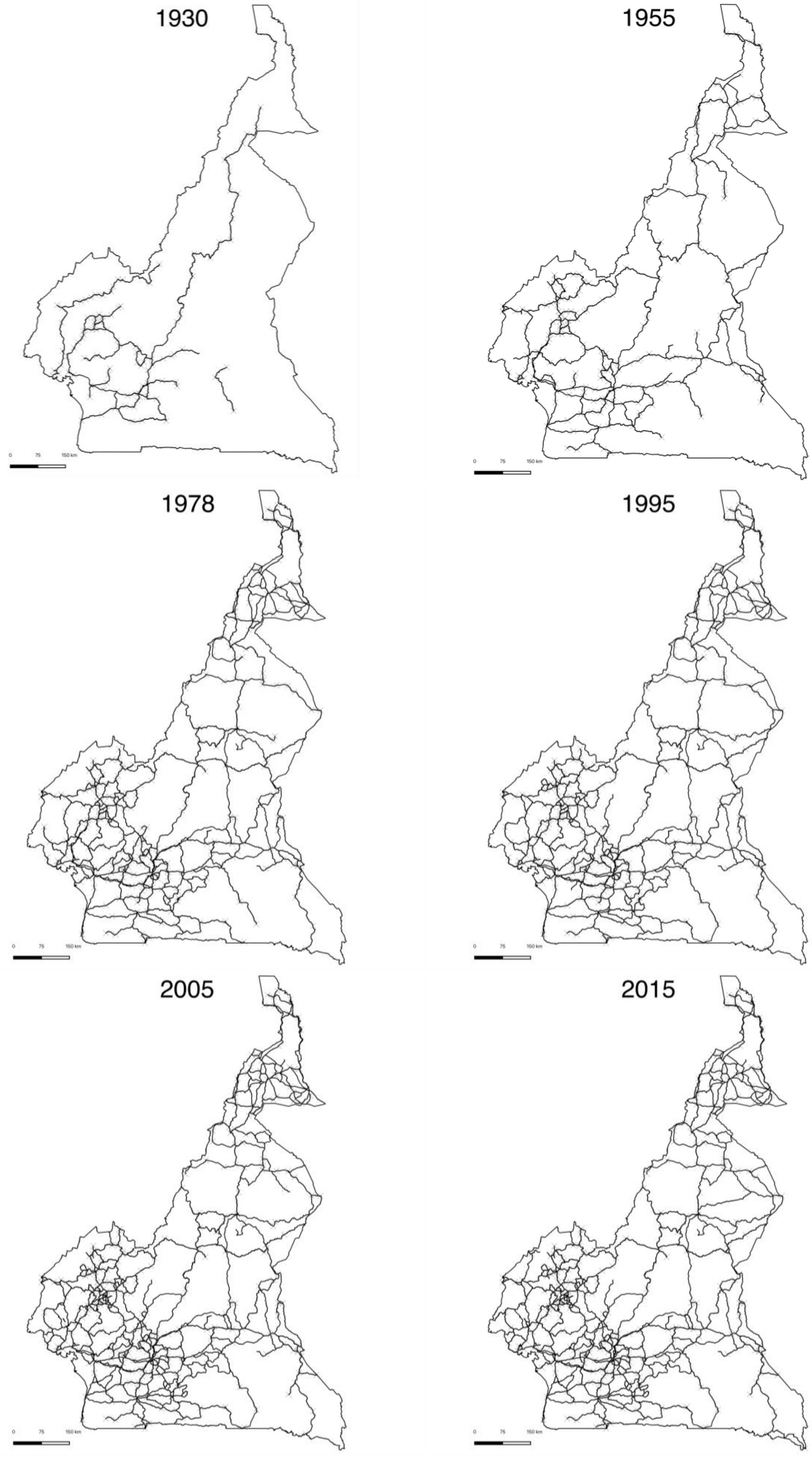


Figure 3.2. Road and rail transport network in Cameroon in 1930, 1955, 1978, 1995, 2005 and 2015
(Source: Author)

For practical reasons, the 1966 map is omitted in this figure but it is detailed in chapter 4. The support for every map contains 875 road and rail sections and 299 localities. We assume that most roads follow colonial alignments (Herbst, 2000) and, when an alternative higher-class road has been built, the old one has continued to exist under a lower category. We assume that the road network has not contracted over time, that is, that secondary or tertiary roads, even if the administrators of the time did not consider them relevant to be mapped in a certain period, have continued to exist under similar conditions from the last inventory. On the contrary, the railways have contracted, in particular from 1991, when the Douala - Mbanga - Nkongsamba rail services stopped[7] and following the 1999 privatisation that discarded the unprofitable section between Otele and Mbalmayo.

Table 3.2 shows how many road and rail sections and how many localities have been included in each map. The decision of including or not a section in each of the maps is based on the official documents and different sources referenced in section 4.

	1930	1955	1966	1978	1995	2005	2015
Sections	247	476	498	719	750	851	869
Localities	107	208	213	286	288	296	299

Table 3.2. Rail and road sections and localities documented in selected year

The length of the documented network was, in 2015, 22 112 km, including railways and paved and gravel roads. It has to be pointed out that until 2010, the non-classified network, mainly rural gravel roads, was thought to be of about 10 000 km. However, the Government conducted in 2016-2018 an inventory of all roads, including local rural and urban segments, bringing the length of non-classified roads to more than 100 000 km. This is the reason why, in this research, we will keep talking about the mapped or documented network, as the real network is several times longer than the kilometres inventoried in 2015. The lengths of the network, the expansion rates and the density of the network over time are indicated in table 3.3.

	1930	1955	1966	1978	1995	2005	2015

[7] The Douala-Mbanga tracks are still used for the maintenance of the Mbanga-Kumba line.

Total population (million)	2.8	3.9	5.4	7.7	13.9	17.5	23.3
GDP (billion) constant 2010 US$	-	-	5.92	10.98	14.35	22.04	33.59
Length network (km)	4,591	10,331	10,731	17,684	18,659	21,291	22,112
Paved roads (km)	0	532	600	1,937	3,771	4,562	5,732
Gravel roads (km)	4,145	9,353	9,680	14,642	13,944	15,812	15,462
Railway length (km)	447	447	452	1,105	944	917	917

Table 3.3. Basic data about Cameroon and its transport network in selected years

A constant surface area of 466 113 km^2 has been considered for the calculations of the network density. This land area corresponds to the figures provided by the National Institute of Statistics. In 1930 and 1955 the aggregated area of the French and the British Cameroon territories was larger, because of the Northern Cameroons. Following a referendum in 1961, this region joined Nigeria at independence. For the sake of simplicity, this study does not take Northern Cameroons into account. In any case, infrastructural development in that territory during the British occupation was very low. According to UK reports to the UN General Assembly, not a single kilometre of road was paved. Moreover, it was a territory more connected to neighbouring Nigeria than to northern French Cameroon, so the influence on the transport network of the future independent country was very low. More details are given in chapter 4.

For ease of visualisation, these maps reflect the transport network for the year indicated but using the borders and administrative regions existing in 2015 (ten regions and fifty-eight departments, and their respective capitals). Even in the years where the administrative divisions were different, we represent the 2015 ones. Thus, in the 1930 and 1955 maps, the Northern Cameroons region does not appear and the borders between the United Kingdom and French territories are not marked. Moreover, while the administrative centres (*chef-lieu*) and other important towns are indicated with dots, only the 2015 regional capitals are labelled: Ngaoundéré, Yaoundé, Bertoua, Maroua, Douala, Garoua, Bamenda, Bafoussam, Ebolowa and Buea.

3.2.3. Topological analysis of the network

Network connectivity

This part of the research is grounded in classical graph theory and network analysis tools. As this research focuses on the efficiency of transport networks, we have looked at authors that study minimum-distance concepts. Bunge (1962) uses topology to solve the problem of the shortest-distance route to connect five points (see figure 3.3).

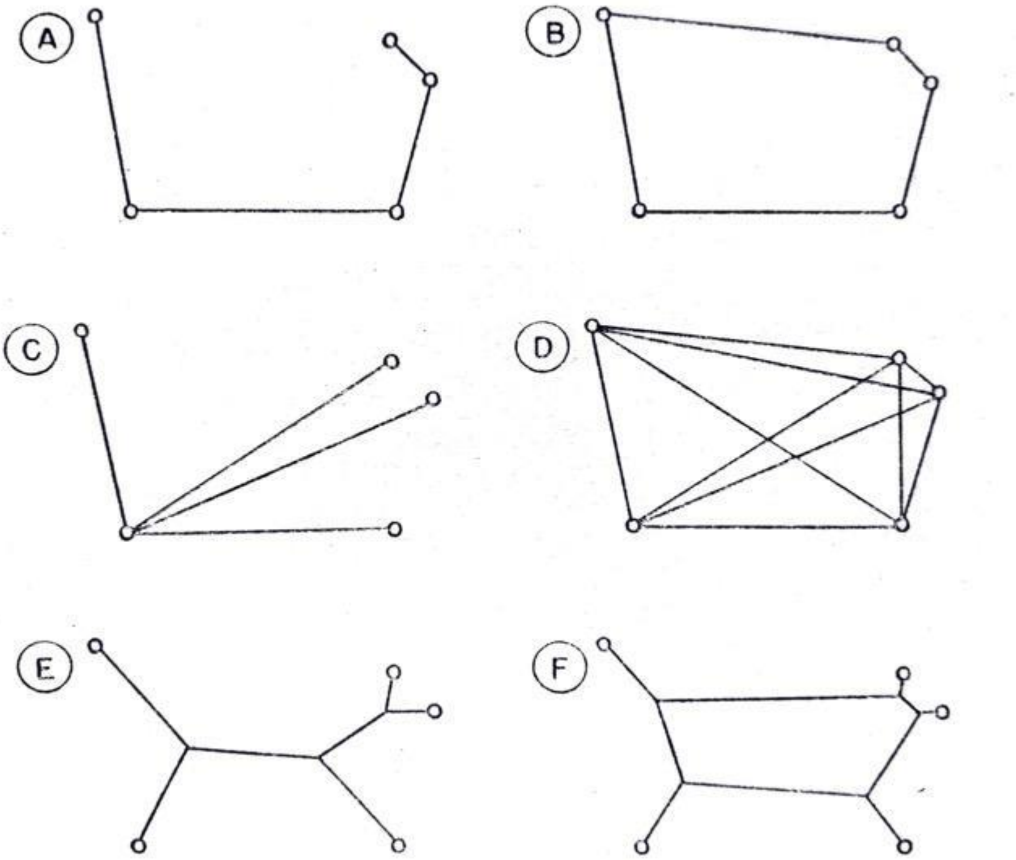


Figure 3.3. Alternative definitions of minimum-distance networks (Source: Bunge, 1962)

The first network (A) shows the minimum distance network starting from a particular point and travelling to all the others following the shortest route; the second (B) shows a similar distance problem, but now the shortest distance around the five points is considered, this is called the 'travelling salesman' type. The next two definitions are for more complex networks in which the concept of hierarchy is introduced. In network C, one point is proposed to connect all the others, while in network D, any point connects to all the others. This latter network would seem to be the most relevant, but as Bunge notes the shortest set of lines connecting all five points (E) does not correspond to any of the above solutions. Finally, the solution F shows the general topological case of a network of lines connecting five points. Solutions D and E are just limiting cases of the general solution (F). If the optimal network is sought, the optimal solution for the user is network D, while for the constructor it is network E.

Bunge explains that in those territories where there is a significant population density, the user's point of view predominates, while in areas of low density the constructor's perspective predominates. However, Bunge was confronted with the computational problems when the number of centres to be analysed increased. Today, thanks to the development of geographical information systems (GIS), including algorithms to analyse networks, shortest-paths calculation can be carried out in complex transport systems.

In each of the seven maps, we have attributed a speed to each road and rail section. For the roads in more recent networks, it is the design speed or the one stipulated by African international standards for primary/national, secondary and tertiary roads. It considers whether a road is paved or not. When road conditions are known, speed is reduced on bad or below good conditions roads. Finally, the speeds have been adjusted to the elevation. When a road is in a region with an average altitude of 500 and 1000 metres above the sea, the speed has been slightly reduced to consider the probability of having steeper slopes. Table 3.4 summarises the speeds used for the network in 2015. For older maps and for the railway, the speeds have been set in consultation with existing historical documents and reports.

Elevation below 500 m above the sea level

	paved			*gravel*		
	good	*fair*	*poor*	*good*	*fair*	*poor*
National	80	60	40	60	50	40
Others	70	50	30	50	40	30

Elevation between 500 m and 1000 m above the sea level

	paved			*gravel*		
	good	fair	poor	good	fair	poor
National	75	55	35	50	40	30
Others	65	45	25	40	30	20

Elevation higher than 1000 m above the sea level

	paved			*gravel*		
	good	fair	poor	good	fair	poor
National	70	50	30	40	30	20
Others	60	40	20	30	20	10

Table 3.4. Speeds assigned to each section of the road network in 2015, in km/h

For every year mapped, we have calculated the shortest path between all pairs of localities in the network. For these calculations, we use GRASS GIS software[8]. These paths are computed taking into consideration the travelling time of each section. The number of shortest paths when the network is connected is equal to $(n^2-n)/2$, where n is the

[8] Version 7.8.4 https://grass.osgeo.org

number of localities. However, because in 1930 and 1955 the network was disconnected, the number of shortest paths is inferior to the maximum possible.

To look at the heterogeneity of the network, the shortest paths allow, among other measures, to establish the detour index. It is calculated as the ratio between the total direct shortest paths distances, as if all the sections had the same speed, and the real transport shortest paths distances, where the sections have an assigned speed as explained in the previous paragraph.

$$DI = \frac{\sum direct\ shortest\ paths(i,j)}{\sum transport\ shortest\ paths(i,j)}$$

The detour index is a good indicator of the discrepancy between the maximum network defined by Raffestin and the real network. Indeed, the ideal network is the one that allows the maximum direct connections between all nodes at the minimum cost, which is what the numerator of the formula represents. The denominator, on the other hand, represents the actual paths as they are calculated using the maximum possible speeds of each section according to its condition and, therefore, the routes that users will take.

Graph theory has a potential usefulness in empirical analysis of transport networks (Taaffe & Gauthier, 1973). In particular, it is adequate to evaluate the connectivity of the network through time. Based on the maps of shortest paths between each node, for each year studied, we have established a planar graph of the road and rail network, where the nodes or vertices (v) represent the 299 localities, and where between each pair of vertices, if connected, there is a single link or edge (e) (figure 3.4). To make the graphs comparable, the number of vertices is constant over the years, as if they already existed in 2015. The number of subgraphs (p) is the number of isolated vertices plus the number of disconnected graphs.

For each of the graphs we can calculate its adjacency matrix A, where $a_{ij} = 1$ when there is an edge between two nodes and 0 in the opposite case. Each link or edge between two vertices i and j can be characterised with three variables: the straight distance between the two points, the real distance, and the real travel time. The real distance and the real time are assigned according to the shortest paths calculation conducted in the real network as explained above. Using the real time, we can run again the shortest path calculations, but this time in the valued graph. The total edge distance is the total number of edges travelled adding all the shortest paths. The diameter is the number of edges travelled between the two most distant vertices in the graph. The degree of a node is the number of adjacent nodes. The average degree is average number of links connected to the nodes rounded up and can be obtained by the expression $|k| = 2e/v$. Table 3.5 summarises some relevant features of the graphs for each of the selected years.

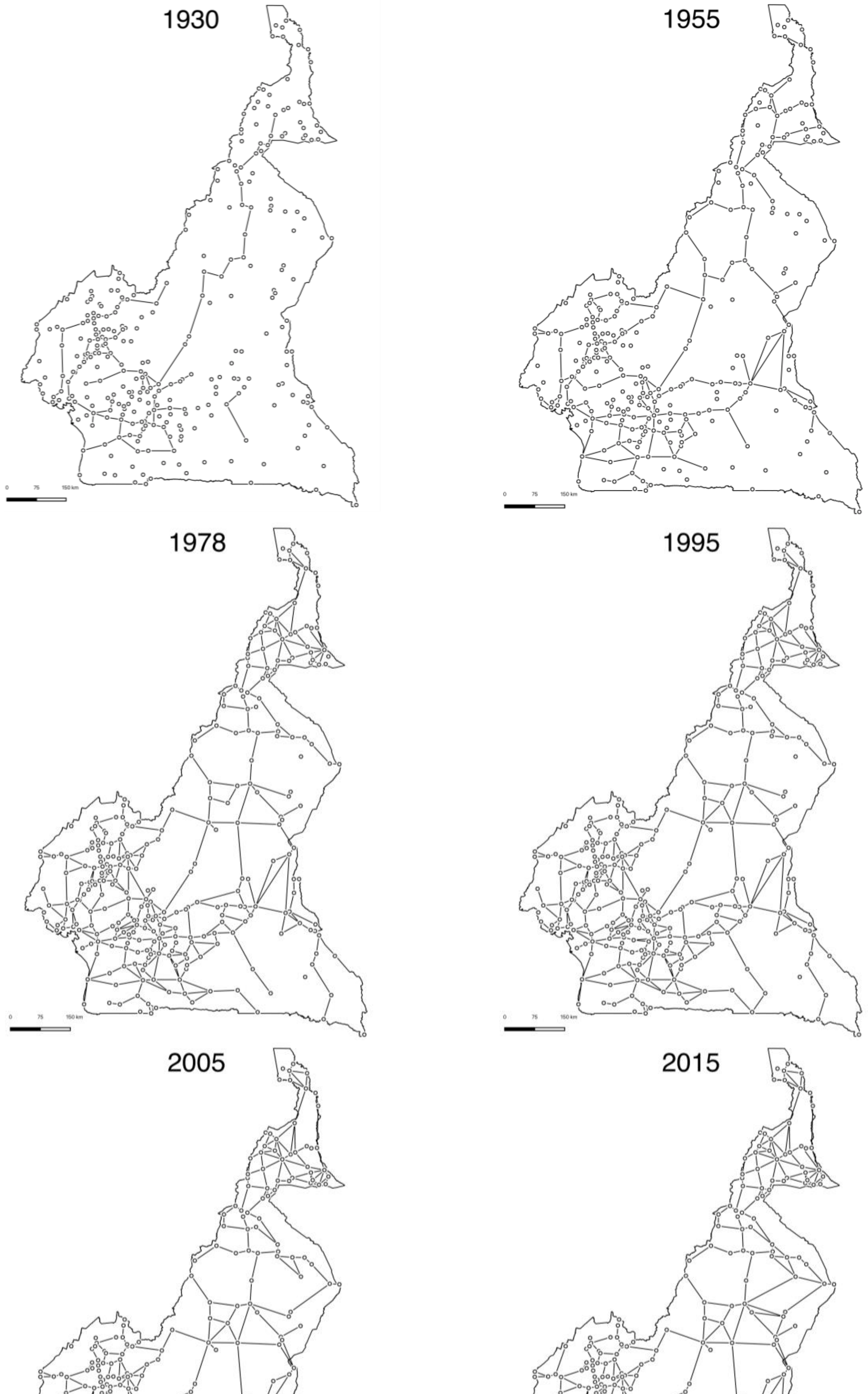


Figure 3.4. Planar graphs generated for each of selected years (Source: Author)

	1930	1955	1966	1978	1995	2005	2015
edges (e)	113	246	263	421	431	456	481
vertices (v)	299	299	299	299	299	299	299
subgraphs (p)	195	93	87	14	12	4	1
connected vertices (v-p+1)	105	207	213	286	288	296	299
total edges distance	41,240	313,609	371,398	602,232	627,228	675,164	723,074
diameter (edges)	32	42	44	41	40	40	45
average degree	1	2	2	3	3	3	3

Table 3.5. Main characteristics of the graph in selected years

With the valued graph, we can calculate a series of indices and measures to analyse the efficiency of the network and compare the situation at different points in time. This efficiency can be calculated both in terms of connectivity of the overall network and of accessibility of the nodes.

At network level, our interest is to see if and how, over the years, the connectivity of the graph has grown. Taaffe and Gauhtier (1973) propose four stages in the development of a transport network (figure 3.5). From a situation of disconnected subgraphs and isolated (stage A), the network passes to a situation of minimal connectivity known as spinal or tree pattern (stage B). When the network offers different alternatives to travel between nodes but the linkage saturation has not been achieved the shape is called grid pattern (stage C). Finally, the delta pattern is attained when the levels of connectivity are high and allow for multiple paths between most nodes with a high degree of circuitry (stage D). As described by Dupuy (1985), stages A and B show low connectedness (*connexité*), because connections between nodes have not been completed yet (missing links). *Connexité* describes the linkages between subsystems, while connectivity refers to the existence of multiple links within a connected network (stages C and D). Understanding this evolution is particularly relevant in the African countries, where the transport systems were initially conceived in the form of trees, as penetration lines to extract raw materials and agricultural products through the seaports (Taaffe, Morrill, & Gould, 1963).

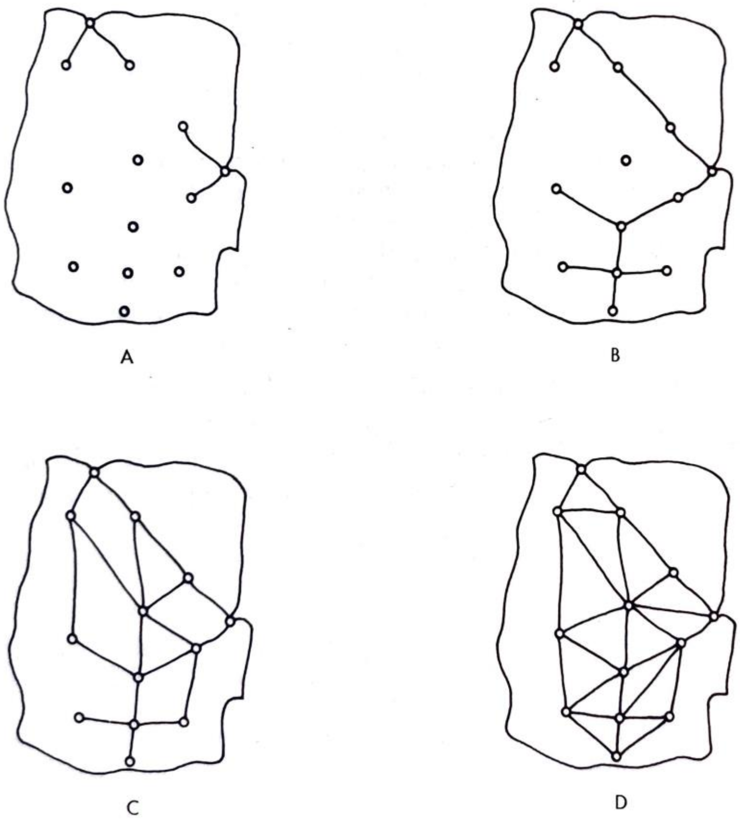


Figure 3.5. Basic patterns in the development of a transport network: isolated nodes/subnetworks (A), spinal/tree pattern (B), grid pattern (C), delta pattern (D) (Source: Taaffe and Gauthier, 1973)

Observing the planar graphs in figure 3.4, we can easily deduce that the network in 1930 followed a tree shape and, in 2015, it has, at least, a grid pattern. However, it is difficult to visually establish at what point the network changed from a tree to a grid pattern. To solve this, Taaffe and Gauthier (1973) use the *alpha* and *gamma* indices of graph theory and determine the range of values where a network should be considered as having a spinal, grid or delta pattern (table 3.6). Garrison (1960) and Kansky (1963) devised the alpha and gamma indices in an attempt to improve the knowledge of the relationship between the geometry of the network and regional development. They established a correspondence between the connectivity and the shape of networks. The alpha index (α)measures connectivity evaluating the number of cycles in relation to the maximum number of cycles for a given number of vertices (v)and edges (e) :

$$\alpha = \frac{e - v + p}{2v - 5} \in [0,1], for\ v \geq 3$$

The closer the alpha index is to 1, the more the graph is connected. On the contrary, values near 0 correspond to trees or spinal patterns. The gamma index (γ) evaluates connectivity in terms of the number of existing edges in relation to the maximally connected graph:

$$\gamma = \frac{e}{3(v - 2)} \in [0,1], for\ v \geq 3$$

A zero value for gamma corresponds to a set of disconnected vertices while, at the other end, 1 expresses a situation where every vertex is connected by an edge to every other possible vertex in the planar graph. This full gamma connectivity situation is very unlikely in planar graphs representing land transport networks.

	alpha index	*where*	**gamma index**	*where*
spinal pattern	$\alpha = 0$	$v = e + 1$	$1/3 \leq \gamma < 1/2$	$v \geq 4$
grid pattern	$0 \leq \alpha < 1/2$	$v \geq 3$	$1/2 \leq \gamma < 2/3$	$v \geq 4$
delta pattern	$1/2 \leq \alpha < 1$	$v \geq 3$	$2/3 \leq \gamma < 1$	$v \geq 3$

Table 3.6. Alpha and gamma indices range for the three basic patterns (Taaffe and Gauthier, 1973)

Noda (1996) proposes a new index combining the alpha and gamma indices, the grid-tree-proportion index (GTP). For general road networks, the GTP index can be inferred from the following two properties of alpha and gamma (Usui and Asami, 2011):

- The value of both the alpha index and the gamma index of general road networks is usually less than that of square lattice pattern road networks with the same number of nodes as are in the general road network.
- The value of both the alpha index and the gamma index of general road networks is more than that of the tree road network patterns with the same number of nodes as are in the general road network.

The GTP index is given by the following equation:

$$GTP = \frac{e - v + p}{(\sqrt{v} - 2)^2} \in [0,2]$$

Usui and Asami combine the use of the three indices, alpha, gamma and GTP to determine the stage of development of a road network. A grid pattern is well laid out if, at least, two of the three indices have a value in the corresponding grid pattern range as shown in table 3.7.

	alpha index	gamma index	GTP index
tree pattern	$0 \leq \alpha < 1/4$	$1/3 \leq \gamma < 1/2$	$0 \leq GTP < 1/2$
grid pattern	$1/4 \leq \alpha < 1/2$	$1/2 \leq \gamma < 2/3$	$1/2 \leq GTP < 1$
delta pattern	$1/2 \leq \alpha < 1$	$2/3 \leq \gamma < 1$	$1 \leq GTP < 2$

Table 3.7. Range of values for each index and the corresponding formation pattern (Usui and Asami, 2011)

In short, the alpha, gamma and GTP indices can be used to establish the level of network development, tree, grid, or delta. The closer the lattice is to the delta pattern, the closer it will be to the ideal or maximum lattice.

Centrality and nodal accessibility

In addition to the evolution of connectivity over time, it is useful to describe the changing importance of the nodes within the graph. In classical transport geography, nodal accessibility or nodality is calculated using the adjacency matrix of the graph, A. The accessibility matrix T is the sum of the adjacency matrix of direct links with all the matrices recording indirect paths, which are the adjacency matrix raised to the successive powers until the diameter D is reached:

$$T = \sum_{k=1}^{D} A^k \text{ where } A^k = \sum_{i=1}^{n} \sum_{j}^{n} a_{ij}^1 a_{ji}^{k-1} \ (\forall k \neq 1)$$

The diameter D is the number of edges in the longest shortest path. The value of the sums of the rows of matrix T gives an accessibility index that allows ranking the nodes. The higher the index, the greater the accessibility of the node. However, this method counts for redundant connections and, to solve it, Shimbel (1953) proposed a shortest-path procedure obtaining a distance matrix from which a more accurate index can be obtained. Yet, the Shimbel index still defines distance between nodes as the number of edges to travel between them, with all the edges having the same value. For the current study on the land transport network, we need to value the graph by assigning to the links the actual time for travelling along them. For this characterisation, current Geographic Information Systems software has proven to be an efficient tool to measure accessibility based on weighted links. In particular, GRASS GIS integrates the most common centrality indicators, closeness and betweenness, as defined by Sabidussi (1966) and Freeman (1977). These centrality indices are also applicable for spatial networks as explained by Barthélemy (2022).

Closeness is, in fact, a measure of the de-centrality of a point, or inverse centrality. The higher the value the less central the node is. Closeness is the reciprocal of farness.

Sabidussi defines closeness as the total geodesic distance from a vertex to all the other vertices in the graph:

$$C(v_i)^{-1} = \sum_{i=1}^{n} d(v_j, v_i)$$

where $d(v_j, v_i)$ is the number of edges between vertex v_j and v_i.

With the use of GRASS GIS software, we can assign the actual time to travel each of the edges of the graph and calculate the closeness as the average time of the shortest paths between the node and all the other nodes in the graph. This calculation only makes sense when the graph is completely connected. Therefore, 1930 has been excluded and 1955 has been included but removing the four localities conforming a disconnected subgraph in the far north of the country.

The betweenness centrality, as defined by Freeman (1977), counts the number of shortest paths going through a given vertex v_k in relation to the total number of possible shortest paths between all the other pairs of vertices v_i and v_j in the graph. It is defined as:

$$B(v_k) = \sum_{i \neq j \neq k}^{n} \frac{\sigma_{ij}(v_k)}{\sigma_{ij}}$$

where σ_{ij} is the total number of shortest paths from v_i to v_j and $\sigma_{ij}(v_k)$ is the number of those paths passing through v_k. In our graphs, σ_{ij} is always 1 because there is only one shortest path between v_i to v_j[9]. We have computed the values for $B(v_k)$ using the network analysis module existing in the GRASS GIS software.

In graphs from different years, the number of connected vertices is different. To make the graphs comparable, we need to normalise the betweenness centrality values by dividing by the total number of possible shortest paths excluding those from and to v_k. This constant for each year can be obtained as:

$$\tfrac{1}{2}(n^2 - n) - (n - 1) = \tfrac{1}{2}(n - 1)(n - 2) = N$$

being n the number of localities in each year. As a result, the expression we have used to calculate the betweenness of the different localities in the graph is given by:

[9] Contrary to the social networks studied by Freeman, in land transport networks, it is rare to have more than one shortest path between two nodes. An example of this could be an urban area, like the Eixample of Barcelona, where the streets have a square lattice pattern.

$$\hat{B}(v_k) = \frac{1}{N}\sum_{i \neq j \neq k}^{n} \sigma_{ij}(v_k) \qquad \text{where } \hat{B}(v_k) \in [0,1].$$

For transport networks, to visualise the results over time, it is practical to use instead edge betweenness. The betweenness of an edge can be obtained by simply assigning the arithmetic mean of the values of betweenness of the two vertices linked by it.

Freeman (1978) proposes a measure derived from the betweenness centrality of each vertex to establish the overall centralisation of a network. An index indicates how central the most central node is in relation to the centrality of all the other nodes in the network. The evolution of this value is useful to see how the resilience of the network improves over time. Reduced values indicate less risk of critical nodes which failure would affect the shortest paths or even cut the network in two or more subnetworks. To compute this index, Freeman proposes the following mathematical expression:

$$C_B = \frac{\sum_{i=1}^{n}[C_B(p^*) - C_B(p_i)]}{max\sum_{i=1}^{n}[C_B(p^*) - C_B(p_i)]}$$

where the numerator indicates the sum in differences between the centrality of the most central node and all the other nodes, and the denominator is the theoretically largest sum of differences in betweenness in any graph with the same number of nodes. When using normalised betweenness, we can substitute the denominator as follows:

$$max\sum_{i=1}^{n}[C_B(p^*) - C_B(p_i)] = n^3 - 4n^2 + 5n - 2$$

3.2.4. Fractal analysis: characterisation of infrastructure provision - Demographic data

Traditionally, indicators to measure the coverage or provision of linear transport infrastructure use the surface area or the number of inhabitants residing in the studied territory. Network density is calculated as length of the infrastructure per square kilometre *(km of infrastructure per 1,000 km2)* or per inhabitant *(km of infrastructure per 1,000 persons)*. We use these indicators because they are useful to study the evolution of the network in a certain territory over time. These values can also be calculated for specific levels of the network (primary, secondary, etc.) or type of infrastructure (railway, paved road, etc.). However, in both cases, it is difficult to compare territories because the administrative boundaries are quite different. The comparison is even more distorted in the case of the length of infrastructure per surface area. This difficulty makes it impossible to define a standard that allows clear comparisons, or it is impossible to apply systematically the same index to different territories.

In the case of Cameroon, with the appropriate population data, these indicators could be measured at regional or/and department level. In section 3.2.2, we explained that the documented network that we have mapped along the years does not include the inventory of rural roads or urban streets. Our study only integrates what were considered the "classified roads" until the 2017 reform[10]. Roads were divided into national, provincial, and departmental. We are analysing the primary network only, which is less than 15% of the total network. Therefore, the figures we would obtain if we calculated infrastructure provision at departmental level would not be conclusive. We would have too little infrastructure mapped per unit area, which would lead to results difficult to interpret. We need a higher scale, and, in this case, it is more appropriate to use the regions as domain of analysis.

To overcome the limitations of these commonly used indicators, Larrosa (2003b) proposes the use of the fractal index F. It is a measure of linear infrastructure provision that combines population, territorial surface and transport infrastructure length:

$$F = \frac{length}{population^p \ x \ surface^s} = \frac{L}{P^p \cdot S^s} \quad p + s = 1$$

Where, for a given region, L is the length of the transport network in km, P is the population in million inhabitants, S is the surface area of the region in km^2, p is the weight given to the population and s is the weight given to the surface area. According to this formula, the more equitable weights p and s would be 0.5. In this way, the territorial model chosen would equally endow both the largest and less populated and the smallest and most populated regions with equivalent/homothetic transport networks. Fair

[10] Présidence de la République du Cameroun (2017), Décret N°2017/144 du 20 avril 2017 portant nomenclature routière

transport policies should tend to this 0.5 value for *p* and *s*, as it helps denser regions to pay for the networks of the other regions. Given a fixed F value as target for infrastructure provision in a specific country, $p > s$ means that transport policies are favouring the most populated areas, and $p < s$ means that infrastructure is being developed in the largest regions with lower population densities. A risk of the first policies is the increase of the infrastructure gap between regions. A risk of the second ones is the need for higher investments and higher maintenance costs in areas where there is less demand.

The F index is fractal because it is indifferent to the various territorial scales of analysis. It has the property of the scaling fractals as described by Mandelbrot (1982) when analysing the relations between length, area, and volume. The F index reflects the tendency of every country to reach an internal equilibrium resulting from transport policies that intend to favour both population and territorial coverage. As financial resources are limited, governments implicitly or explicitly make choices based on giving more weight either to the population or to the surface. The fractality of the transport networks implies that, for a given network, the same law of distribution is observed for different scales. This property allows for several applications of the fractal index. Larrosa proposes to use it for spatial planning, by fixing a value for F as a territorial standard. For instance, thanks to F, once the population and the area are fixed, the length of the network is unambiguously determined. Rodriguez Dalmau (2012) uses the index F to compare the evolution of the British, German, and Spanish transport policies over a period of time and, thanks to it, is able to demonstrate a more efficient territorial planning in the case of the UK and Germany. The F index is particularly convenient in explaining the infrastructure endowment over time of a developing country like Cameroon because we can establish at a certain point in time which aspects the materialisation of transport policies placed more emphasis on, whether it was on population or on surface area.

The properties derived from the fractality of the F index also allows us to overcome the difficulty in the case of Cameroon of not having enough detail of the transport network at departmental level. Given the territories A and B in the same country, not necessarily adjacent, in which there are, respectively, transport network lengths L_a and L_b, areas S_a and S_b, and populations P_a and P_b, then the following is true:

$$F = \frac{L_a}{P_a^p \cdot S_a^s} = \frac{L_b}{P_b^p \cdot S_b^s} = \frac{L_a + L_b}{(P_a + P_b)^p + (S_a + S_b)^s}$$

This expression tells us that what is satisfied in territory *A* is identical to what is satisfied in territory *B*, and also in *A+B*, so that the characteristic of the whole territory is identical to each of the parts and not to the sum of the parts. This property allows us to compare the departments or regions with each other, or with the entire country, as well as with certain aggregate sets of regions that we may form.

In 1930, the existing demographic data about colonial Cameroon is not accurate enough in a way that can be used for the purpose of this research. Between 1955 and 2005, the available data in terms of population in Cameroon is quite complete at regional and departmental level. The population per subdivision in 1955 can be obtained from the UK and France annual reports presented to the UN General Assembly during the Trusteeship. In the French part, after independence, most of the subdivisions have been preserved as departments. Some merely changed names and others were divided into smaller units. On the British side, the six divisions were split internally into smaller units to create the departments. Therefore, in both territories, the population in 1955 of the subdivisions not having a direct correspondence with the future departments can be calculated as a prorata of the total population division in 1955 using the internal distribution of the 1967 population data[11]. The same procedure has been applied to obtain the population per department in 2015. We use the estimates given by the National Institute of Statistics for the ten regions and we apply the distribution ratios existing in the 2005 census. Obviously, this involves a certain amount of error, as departments in the same region may have grown at different rates. For the rest of the years, we have used the official census in 1976, 1987 and 2005[12] that gives the total population per department and per region. These administrative divisions have remained constant until today.

3.2.5. Estimation of transport investments over time - Financial data

As explained in the introduction, the problems Cameroon has been facing since 2014 suggest that the country may be entering a period of premature infrastructure stagnation. To respond to this question, it is necessary to establish the past levels of investment and to compare them to the current situation. The following methodology is used:

1. Identification and quantification of the investments carried out during the three expansion phases 1884-1930, 1946-1985 and 2006-2018. These time intervals are indicatively established based on the historical review. We obtain the amounts disbursed in transport projects from the consulted colonial reports, plans, documents, and studies used in the geohistorical review contained in chapter 4. For the most recent years, we use publicly available financial data from the Ministry of Finances on the State budget for investment in transport[13].

2. Collection of data on yearly tax revenues: from 1884 to 1987, the main source is Manning (1990). From 1985 to 1993, we base our calculations on Aerts (2000).

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[11] Office de la recherche scientifique et technique Outre-Mer-ORSTOM, 1971, Tableau de la Population du Cameroun, 3ème édition.

[12] Premier, Deuxième et Troisième Recensement Général de la Population et de l'Habitat du Cameroun, Gouvernement du Cameroun

[13] Republic, of Cameroon, Directorate General of Budget, https://www.dgb.cm

Finally, for the most recent period between 1994 and 2018, data tax revenue can be obtained online from the World Bank website[14].

3. Conversion of the monetary values to 2018 constant prices:

    a. For tax revenue: Manning provides the real tax revenue in 1970 French Franc prices. According to the *Institut national de la statistique et des études économiques (INSEE)* on-line calculator, considering currency erosion due to inflation, the purchasing power of 1.00 Francs in 1970 is the same as that of 1.10 Euros in 2018[15]. For Aerts, as the parity between the French Franc and CFA Franc was fixed at 1 CFA Franc = 0.02 FR Franc, we use the same INSEE procedure to convert into 2018 Euros. From 1990, we have tax revenue data from the World Bank at current CFA Franc prices. We convert those figures to 2018 Euro prices by applying the inflation rates provided by the National Institute of Statistics in Cameroon [16] and using the fixed parity of 1 Euro = 655.957 CFA Franc.

    b. For transport investment expenditure:

        i. For the period 1884-1930, we have only been able to gather financial data about rail investments. Conversion to 2018 prices is based on the French INSEE calculator and, for Germany, on the purchasing power equivalents sheet available in the Bundesbank website[17]. For road investments, we estimate the value of the expenditure assuming that all the roads were built with gravel surface and single lane standards and multiplying the length by a cost per km of 100,000 Euros, 2018 prices. This unit cost has been estimated based on information available in Porte (1930).

        ii. For the period from 1946 until 1985, we convert to 2018 prices using the INSEE on-line calculator. For investment in the British Cameroons in the 1946-1960 period, we base our calculations on the site MeasuringWorth.com[18].

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[14] The World Bank, Data, Cameroon, Tax revenue (current LCU), https://data.worldbank.org/indicator/GC.TAX.TOTL.CN?locations=CM

[15] République française, Institut national de la statistique et des études économiques, Convertisseur franc-euro: https://www.insee.fr/fr/information/2417794

[16] Republic of Cameroon, National Institute of Statistics, https://ins-cameroun.cm/en/

[17] Deutsche Bundesbank, Purchasing power equivalents of historical amounts in German currencies, https://www.bundesbank.de/resource/blob/622372/87bb480b1c663920e787ace4585e40f0/mL/purchaising-power-equivalents-data.pdf

[18] https://www.measuringworth.com/calculators/ukcompare/

iii. Between 2006 and 2018, we convert to constant prices in 2018 by using the inflation rates from the Cameroonian official statistics and the fixed exchange rate of 1 Euro = 655.957 CFA Franc.

3.2.6. Road deterioration models

We examine the question on the sustainability of road infrastructure through the cost-effectiveness of enforcing axle-load regulations over a period in the Douala-N'Djamena corridor in Cameroon. This part of the research is published in our paper Torres Martinez *et al.* (2018), which structured as follows:

1. Context:
   a. Extent of the problem of trucking overloads in Sub-Saharan Africa. Classic references.

   b. Description of a problem that has lasted since the 1960s. The fight against overload has had few satisfactory results. We explain the reasons of this failure and describe the better-known cases (corridors in West Africa).

   c. We recall classic references economic impact of pavement deterioration combined with lack of proper road maintenance.

   d. We explain that the success stories promoted by official aid to the sector are valuable, and that it is important to quantify the economic impact of good policies and investments on overload control. All this in a context of reduced investment in roads in Sub-Saharan Africa and criticism of the effectiveness of official aid.

2. Enforcement of axle-load regulations in Cameroon:

   a. History of the application of the load control system in Cameroon. Vicissitudes, political pressures, etc. Applicable regulations.

   b. The functioning of the current system: privatisation of activities, number of weighing stations, technical systems used, investment budget, main figures of the heavy trucks control, fines, tolerances, unloading systems, equipment maintenance, anti-fraud measures, authorizations to circulate overloaded, etc.

   c. Evaluation of the operation. Impact on the reduction of overloads since 2003.

   d. The following steps are introduced at this point: the impact on the national economy of the operation of this system must be estimated, compared to the "do nothing" situation in many other countries. We explain that the analysis is limited to the international corridors in Cameroon, but that an extrapolation can be made since the reduction of overloading affects the entire network and not only the international routes.

3. Estimating cost-effectiveness of axle-load control in Cameroon

a. Definition of "ex post" study alternatives (for the period 1995-2015)

- alternative 0: if the situation before 2003 had remained uncontrolled.
- alternative 1: what has actually happened, real control
- alternative 2: what would have happened if overloading had been optimally controlled = zero overloading, without ad-hoc ministerial authorisations and with systematic unloading of overloaded trucks

b. Defining the network that will be analysed

c. Calculation of pavement deterioration in the 3 alternatives with HDM4[19] submodel PRD.

d. Conservation and rehabilitation costs. We explain the problem of the Road Fund. Estimate the possible cost differences between the 3 alternatives

e. Calculation of the vehicle operating costs (VOC) in the 3 alternatives with HDM4 submodel VOC. The analysis is well detailed here, as the actual composition of the heavy traffic is known. We consider the time savings and their conversion into EUR in the model. Also consider the different CO2 emissions per alternative (lower speed, higher emission per km driven → use HDM4).

f. It is important to work with shadow-prices since the impact on the national economy is to be estimated (economic CBA). Therefore, we will obtain the market costs of fuels, lubricants, construction, etc. and eliminate the taxes.

g. Estimation of the load control system costs (investment, operation).

h. Summary table (on the international corridor and - if applicable - extrapolated to the main network):

	Alt 0	Alt 1	Alt 2
VOC light			
VOC trucks 1			
VOC trucks 2			
VOC trucks 3			
VOC buses			
…			
VOC total			
Time savings			

[19] http://www.hdmglobal.com

	Alt 0	Alt 1	Alt 2
CO_2 emissions			

4. Conclusions: The basic indicator to obtain is x€ savings in VOC / 1€ investment in effective overload control.

To calculate the load equivalency factors (LEFs), a simplified fourth-power ESAL formula is frequently used. This is the case of the annual weighing reports published by the Cameroonian Ministry of Public Works:

$$LEF = \left(\frac{P_i}{P_{ref}}\right)^{\alpha}$$

where:

P_i = axle load recorded

P_{ref} = standard 80-kN single-axle load

α = power factor (generally equal to 4 for flexible pavement)

However, when implementing a comprehensive simulation model as HDM-4, to assess the impact of axle-load limits, LEFs can be estimated by applying the method established in *Appendix MM* of the *AASHTO Guide for Design of Pavement Structures* (AASHTO, 1986). The complete ESAL equation for flexible pavement is:

$$\frac{W_x}{W_{18}} = \left(\frac{L_{18} + L_{2s}}{L_x + L_{2x}}\right)^{4.79} \left(\frac{10^{G/\beta_x}}{10^{G/\beta_{18}}}\right) (L_{2x})^{4.33}$$

where:

W_x = axle application inverse of equivalency factors (where W_{18} = the number of 18,000-lb (80-kN) single-axle loads)

L_x = axle load being evaluated (kips)

L_{18} =18 (standard axle load in kips)

L_{2x} (code for axle configurations)

= 1 (single axle)

= 2 (tandem axle)

= 3 (triple axle)

L_{2s} (code for standard axle) = 1 (single axle)

$G = Log_{10}\left(\frac{4.2 - p_t}{4.2 - 1.5}\right)$ a function of the ratio of loss in serviceability at time t to the potential loss taken at a point where $p_t = 1.5$

p_t = "terminal" serviceability index (point at which the pavement is considered to be at the end of its useful life)

$\beta = 0.4 + \left(\frac{0.081(L_x + L_{2x})^{3.23}}{(SN + 1)^{5.19} L_{2x}^{3.23}}\right)$ function that determines the relationship between serviceability and axle load applications

SN = structural number

As can be observed, the ESAL equation derived from the AASHO Road Test allows for a much more accurate calculation of LEFs as it takes into account the road structure, its deterioration and the axle type (single, tandem or tridem). Moreover, this is a more coherent approach since the structural number and road conditions are key variables of HDM-4.

4. Geohistory of the transport infrastructure network in Cameroon

4.1. Patchwork in an interconnected world: is Cameroon a piece of the mosaic or a mosaic in itself?

As in most African States, current national borders and spatial organisation in Cameroon are the result of decisions taken during the colonial period and at the time of the accession to independence. In the case of Cameroon, the way history has exerted influence in the transport systems is even more complex because of having been ruled by three colonial powers, Germany (1884-1914) and France and the United Kingdom (1914-1959). Interestingly, as we will detail, as far as investments in transport are concerned, Cameroon has been the object of special treatment, first by the colonial powers and then, by foreign donors. With a strategic geographical location between the Gulf of Guinea, the Sahel, and the Congo Basin, and richly endowed with natural resources, the efforts to develop its full economic potential by providing means of transport have been significant. Today's transport system is still far from fulfilling its function.

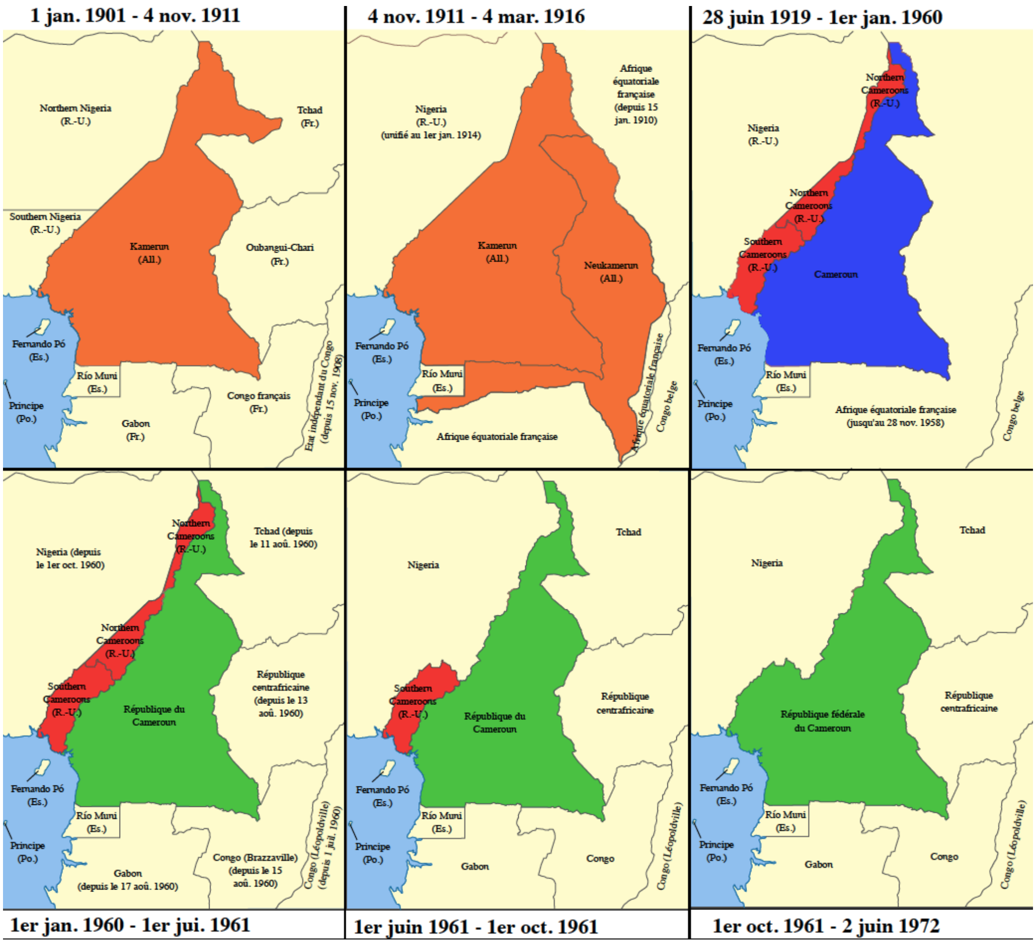

Figure 4.1. Cameroon boundaries evolution over time from colonial times until independence (Source: Wikipedia[20], CC-BY-SA-4.0)

[20] https://commons.wikimedia.org/wiki/File:Cameroon_boundary_changes-fr.svg

Cameroonian borders evolved in accordance with international agreements both during the colonial era and at the time of the country's accession to independence. As can be observed in figure 4.1, except for a few years preceding World War I, between 1911 and 1916, where Germany expanded its possessions thanks to an agreement with France[21], most of the core territory has remained fundamentally the same. The most relevant event related to the delineation of the borders having an impact in the transport network was the separation of the fifth part of Cameroon located in the West, which between 1919 and 1960, was ruled by the British (red in the map). Consequently, the transport system along this narrow strip was designed seeking coherence with Nigeria and not with French Cameroon (which in turn developed with its back to Nigerian territories). At independence, in 1961, only the southern part of British Cameroons re-joined the new Federal Republic. Since then, borders have remained unchanged.

The evolution of the transport network in Cameroon is in appearance common to most of the African colonial territories as Taaffe, Morrill and Gould described it in 1963 (figure 2.2). In this research, we intend to analyse not only whether this model and Debrie's thesis are applicable to the Cameroonian case, but also at what point in time it can be considered to have moved from one phase to another. In our contribution to the study of the transport networks in Sub-Saharan Africa (Oliete Josa and Magrinya, 2018), we propose a timeline based on the Taaffe, Morrill and Gould model where we characterise each phase of the network development in relation to the existing policies and transport functions and by placing it in its economic and political context (figure 4.2). We stress the importance of zooming in on major metropolitan areas to understand how urban infrastructure development is related to the emergence of high-priority "main streets".

A priori, one could say that the case of Cameroon corresponds to the timeline proposed as we can differentiate three different infrastructure expansion-stagnation cycles, with three different perspectives. Indeed, in Cameroon, from 1884 to 1930 there was a slow but continuous network expansion period. It was followed by a stagnation period in the aftermath of the great depression and until the end of World War II (1930-1945). The second cycle (1946-1960) would start with what is called the FIDES Era, a French programme that significantly contributed to extending infrastructure in Cameroon during the last fifteen colonial years. This growth period continued throughout 25 years after independence (1960-1985). From 1986, Cameroon, as other African countries, entered into an economic crisis that drastically reduced the investments until the beginning of the twenty-first century (1986-2000). The past 20 years have seen a burgeoning in the number of large infrastructure projects started (2001-2020). However, from mid-2014, Cameroon got into financial and political troubles. It is a period marked by a sudden increase of external and internal debt, low oil prices and a number of political and security crises, with similar characteristics to the ones of previous stagnation years.

[21] Accord franco-allemand du 4 novembre 1911 relatif au Congo, L'Afrique Française, novembre 1911, pp. 412-431.

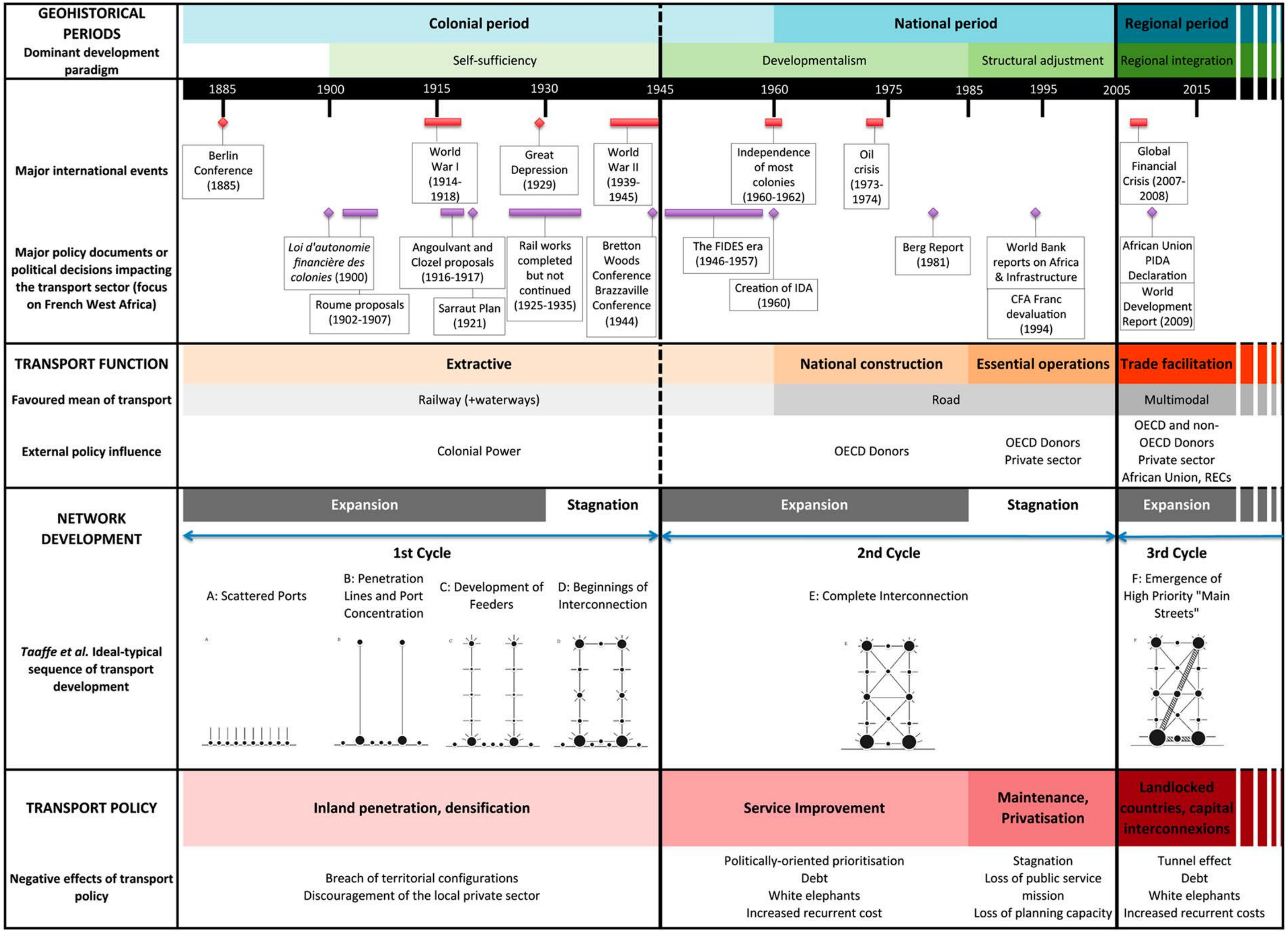

Figure 4.2. Timeline explaining the evolution of the transport networks in Sub-Saharan (Source: Oliete Josa & Magrinya 2018)

Whether the evolution of the transport network in Cameroon has followed the sequence we described in our 2018 paper is a question we try to answer in this research. We examine the correspondence between the political strategy and its actual implementation. We study the impact of the decisions made on the efficiency of the network looking also at the effectiveness of those policies both in terms of time lapse until they are executed and of mismatch with the actual goals. Ultimately, we intend to elucidate if Cameroon has the risk of entering into the stagnation phase of a third infrastructure cycle and try to draw conclusions from previous periods from which new transport policies could benefit.

An important finding of the article we published in 2018, as well as the book chapter comparing the evolution of transport network planning schemes in Europe and Africa (Oliete Josa & Magrinyà, 2022), is the pivotal role of metropolitan infrastructure in forming the network and the relevance of prioritising investments in the urban centres. Using the urban planning model and its relationship with the territory proposed by Magrinyà (2002), we adapted the Taaffe, Morrill and Gould model by adding enlarged representations at the level of an interior urban centre (figure 4.3).

This closer look is useful to better understand how African cities are placed in the context of the local, national, and international systems that they serve. In their model, Taaffe, Morrill and Gould bring forward the idea that the last phase is actually a repetition of the previous processes but at a higher scale, which is in line with the hierarchical organisation of the territory anticipated by Christaller and the infrastructure-led reorganisation of urban areas. Analogously, at a lower scale, following a fractal logic, a process of concentration and prioritisation of linkages can be established. Therefore, the initial stages of scattered ports and the introduction of inland transport modes correspond to the traditional city systems, where the role of nodes predominates, and transport modes are limited (B). With the progressive introduction and extension of arterial and feeder railways and roads, localities expand, first around the city centre (C) and gradually along the transport lines (D). The complete interconnection at the national level arrives with the generalisation of modern motorised transport modes, which in turn drastically changes the appearance of cities (E). However, access cannot be spatially uniform and numerous geographical areas and social groups are left segregated (E). This significant increase in communication speed creates a "tunnel effect", whereby it becomes possible for a node to establish relationships with another node that is located at a great distance, without improving its connections with another contiguous node, giving rise to trans-local relationships as opposed to traditional local relationships (Herce & Magrinyà, 2002).

Therefore, the last and current phase of transport development should be conceived not only focusing on the emergence of high priority “main streets”, nowadays more commonly known as international trade corridors. Inclusiveness and integration of regional cities in the territorial networks are critical. Addressing the weaknesses of secondary transport networks encircling cities is an investment need comparable to interconnecting major African capitals. In this respect, this research specifically looks to the relationship between the existing urbanisation trends and transport networks in Cameroon.

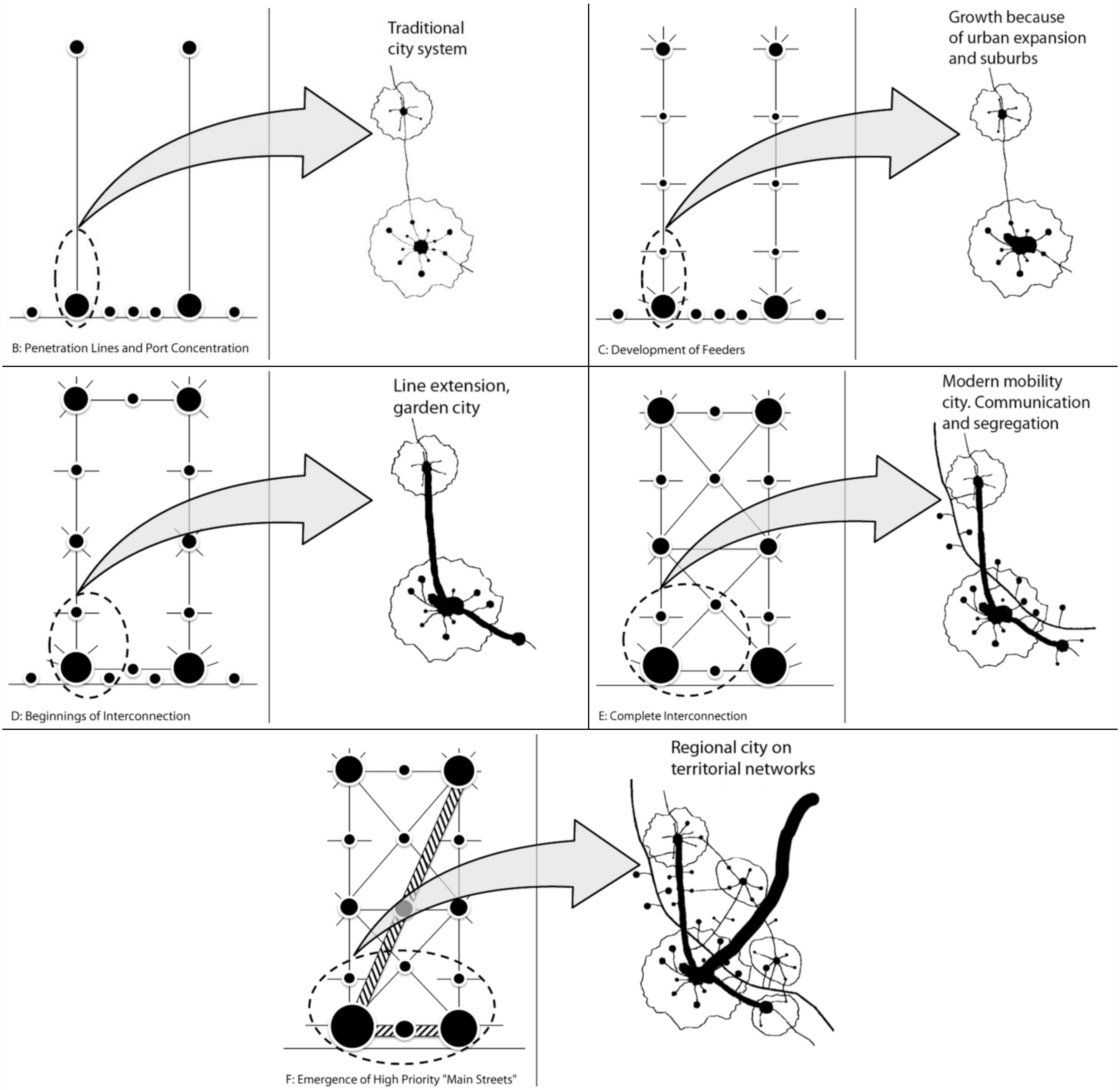

Figure 4.3. The correspondence between the sequence of Taaffe, Morrill and Gould (1963) and the metropolisation process model shaped by transport infrastructure
(Source: Author based on Magrinya, 2002)

4.2. Major historical events and impact on the network in Cameroon

4.2.1. From imperial plans to the root causes of underdevelopment (1884-1945)

Before Germany officially annexed Cameroon in the Berlin Conference that took place in 1884-1885, the borders were not in any form comparable to what we know today (Owona, 1996). There were at least two hundred distinct societies (figure 4.4). The numerous ones located in the current West (Bamiléké grassfields) and north (Fulani savanas) had a political system in the form of a state (kingdoms, chiefdoms, sultanates or lamidats). The strength of these political systems and socio-cultural structures has allowed them to endure, albeit subordinate first to the colonial powers and then to the Republic. Between 1884 and 1913, starting from the first settlements on the coast, Germany drew the borders of its new territory with the help of explorers, by making pacts with local chieftains and on the basis of agreements with the British and the French.

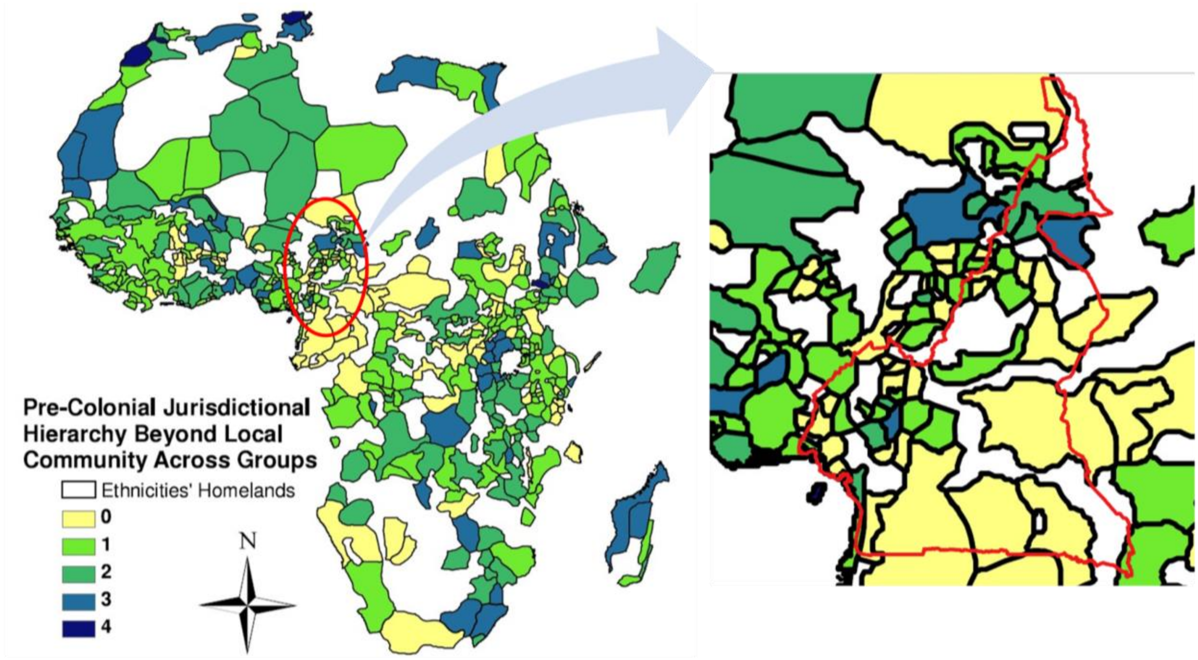

Figure 4.4. Political jurisdictions above the local (usually village) level for each ethnicity
(Source: Murdock, 1967, as cited in Michalopoulos & Papaioannou, 2015)
A 0 score indicates stateless societies "lacking any form of centralised political organisation." A score of 1 indicates petty chiefdoms; a score of 2 designates paramount chiefdoms; and 3 and 4 indicate groups that were part of large states

In 1900, German colonies in Africa had 508 km of rail tracks and were far behind England and France that had 7,177 km and 4,567 km respectively (René, 1905). However, in the decade before the First World War, Germany added 4,500 km to its railway network, a growth rate outpacing the kilometres built by the other colonial powers (Gann, Duignan, & Turner, 1969). In this respect, for the Germans, Cameroon was considered one of the best places to invest. Despite being a territory with a steep relief and low navigability waterways, particularly unsuitable for inland transport (Njoh, 2017), Cameroon has different valuable agro-ecological zones, going from the Sahel to the Rainforest, which offer the possibility to obtain yields of a wide range of crops (figure 4.5).

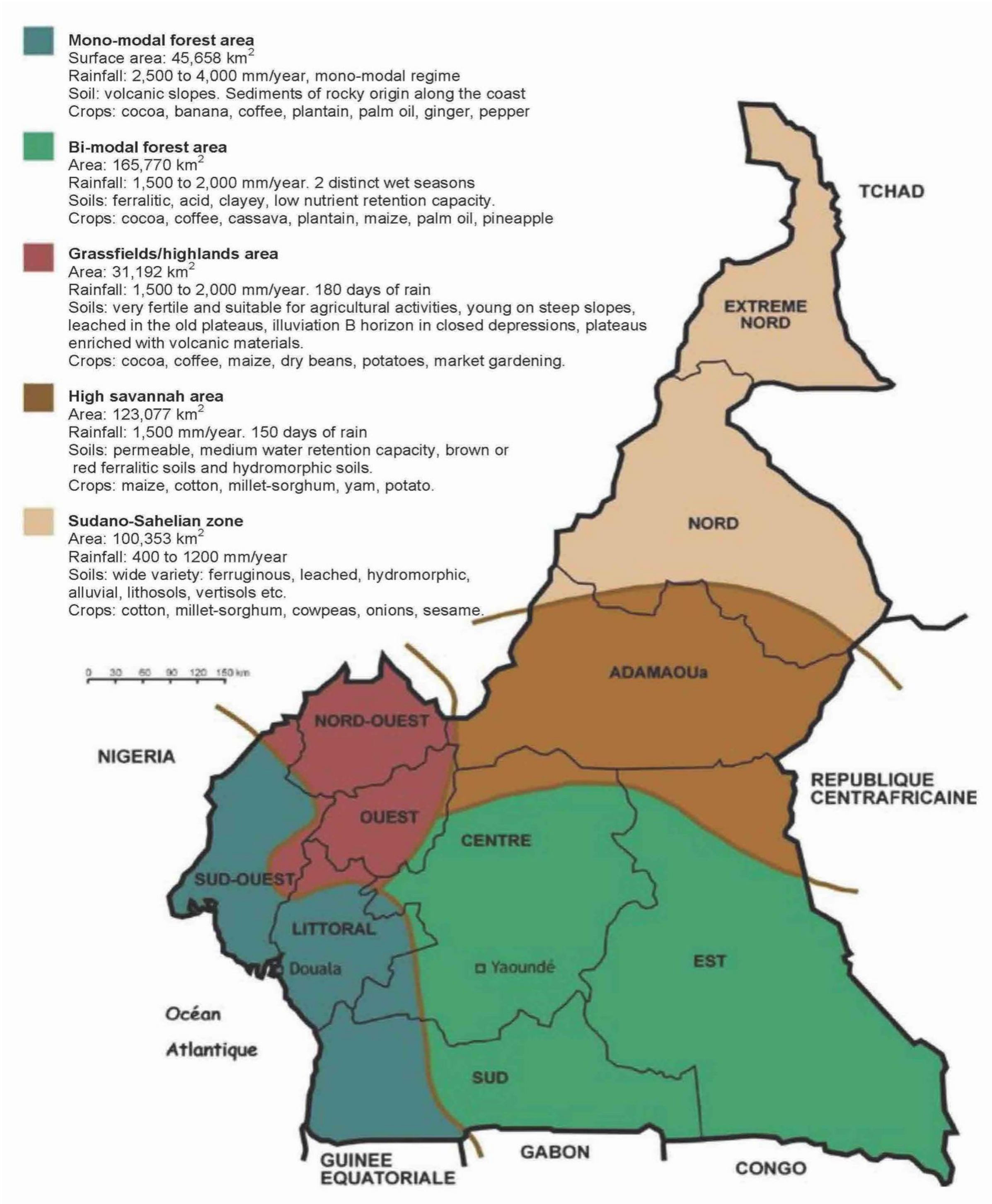

Figure 4.5. Main agro-ecological zones in Cameroon (Source: IRAD)

The agricultural potential and the hard-to-reach hinterland sparked off an intense debate on what penetration lines had to be prioritised. In spite of some German imperialistic ambitions to build a transcontinental link from Douala to Dar-es-Salaam crossing the

French and Belgian territories (Clarke, 1966), colonial authorities were mainly motivated by trade opportunities and short-term economic returns. In the case of Cameroon, private trade interests were significant drivers of investment (Conrad, 2011). Publications from the time (Meyer, 1902; René, 1905) indicate the possible penetration lines from the coast based on the existing port system and navigable rivers. Figure 4.6 indicates with arrows the direction of those possible penetration lines and table 4.1 describe the routes:

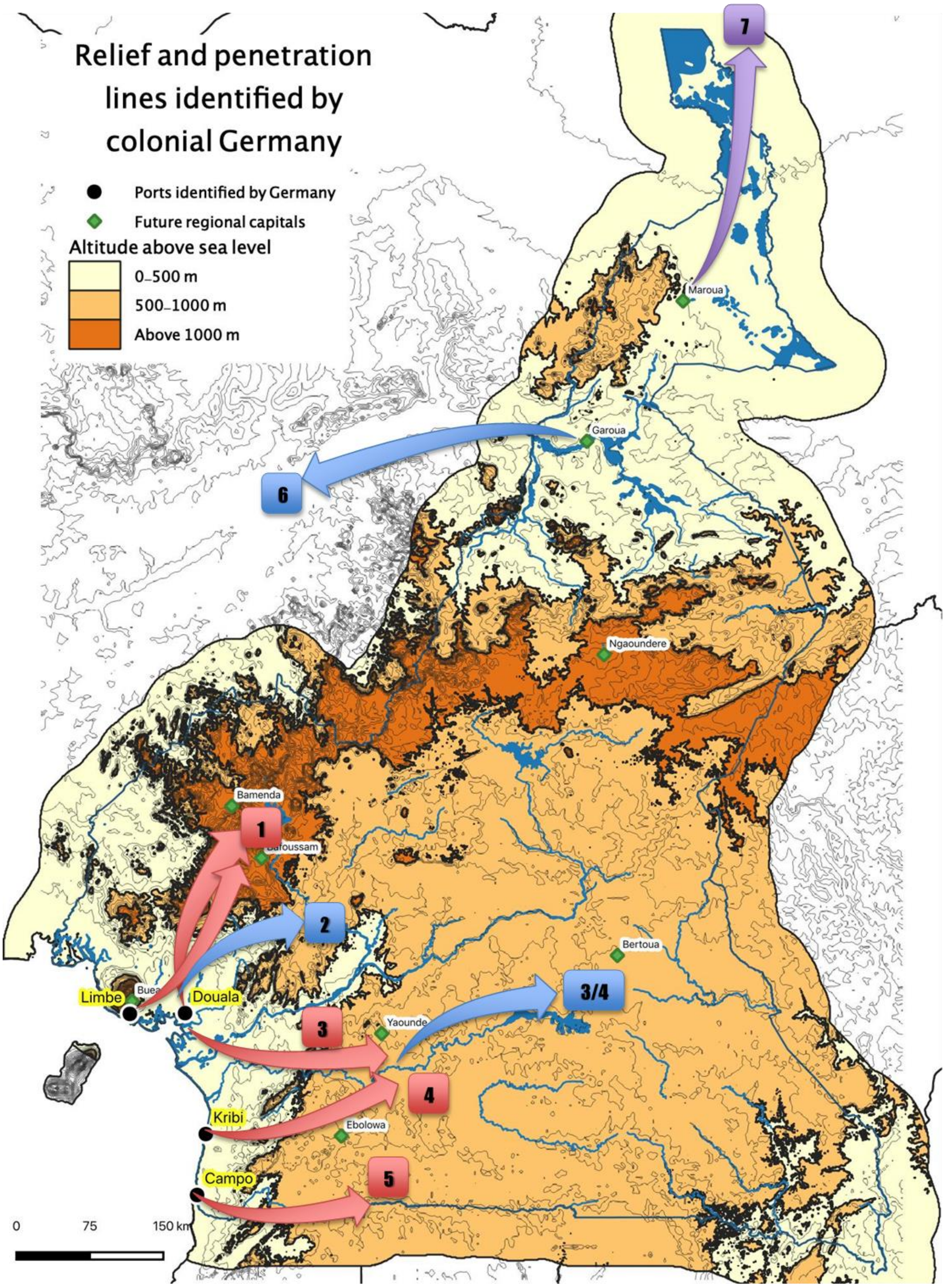

Figure 4.6. Main penetration lines identified by Germany in the initial years of the colony (Source: Author)

	Origin	Route	Mode
1	Doula or Victoria (Limbe)	Along the Mungo river, via Dschang, going northeast to Garoua and Lake Chad	Railway
2	Douala	Wouri river to Yabassi	Waterway
3	Douala	Eastwards, via Edea, to the Nyong River, a place called Widimenge close to Yaoundé	Railway Waterway
4	Kribi	From the coast to the Nyong river	Railway Waterway
5	Campo	Eastwards parallel to the border with the Spanish Muni River territories	Railway
6	Garoua	To the Niger Delta, through neighbouring Nigeria	Waterway
7	Maroua	To the Mediterranean coast, though the Sahara Desert	Animal caravan

Table 4.1. Main penetration lines identified by Germany in the initial years of the colony

Overall, Germany identified two options to reach in the long term the Adamaoua and the Lake Chad from the coast: a northeast line, going through the western high grassfields and the Foumban sultanate, and an east line going through the tropical jungle following the lower and middle course of the Sanaga river. For the first part, the first option was more advantageous since it had to go through easier geography, more favourable agricultural lands and more populated areas. The latter allowed for a better coverage of the territory and passed by less mountainous areas. The northern territories of German Cameroon could also be reached by the Benue River, a Niger affluent going through the interior of British Nigeria. However, the Germans ruled out this option to ensure the autonomy of the supplies (Rudin, 1938) and because they estimated an insufficient capacity of the Benue River (Sunderland, 2018).

The first proposal presented to the Government, a railway from Victoria to the areas surrounding Mount Cameroon, was abandoned to avoid competition with the 600 mm narrow-gauge railroad being built by the West African Planting Society Victoria (Rudin, 1938). Finally, the Nordbahn to Nkongsamba was decided from Bonaberi, opposite to Douala, on the other bank of the Wouri River (see figure 4.7). Works started in 1907 and ended in 1911. Despite problems related to the expropriation of the land, the project was completed on time and became a financial success. The 160 km railway was the first private investment in the German colonies, and it was profitable a year after it entered into service. Spurred on by the first project, colonial administrators designed the Mittellandbahn, a railway running 360 km from Douala to the Nyong river. Works started in 1909. This time, the promoters could mobilise funds from the Reichstag budget and public loans. However, due to land and labour conflicts in the colony, and to the beginning of World War I, only 150 km, up to Bidjoka (close to Eseka), could be finished in December 1913.

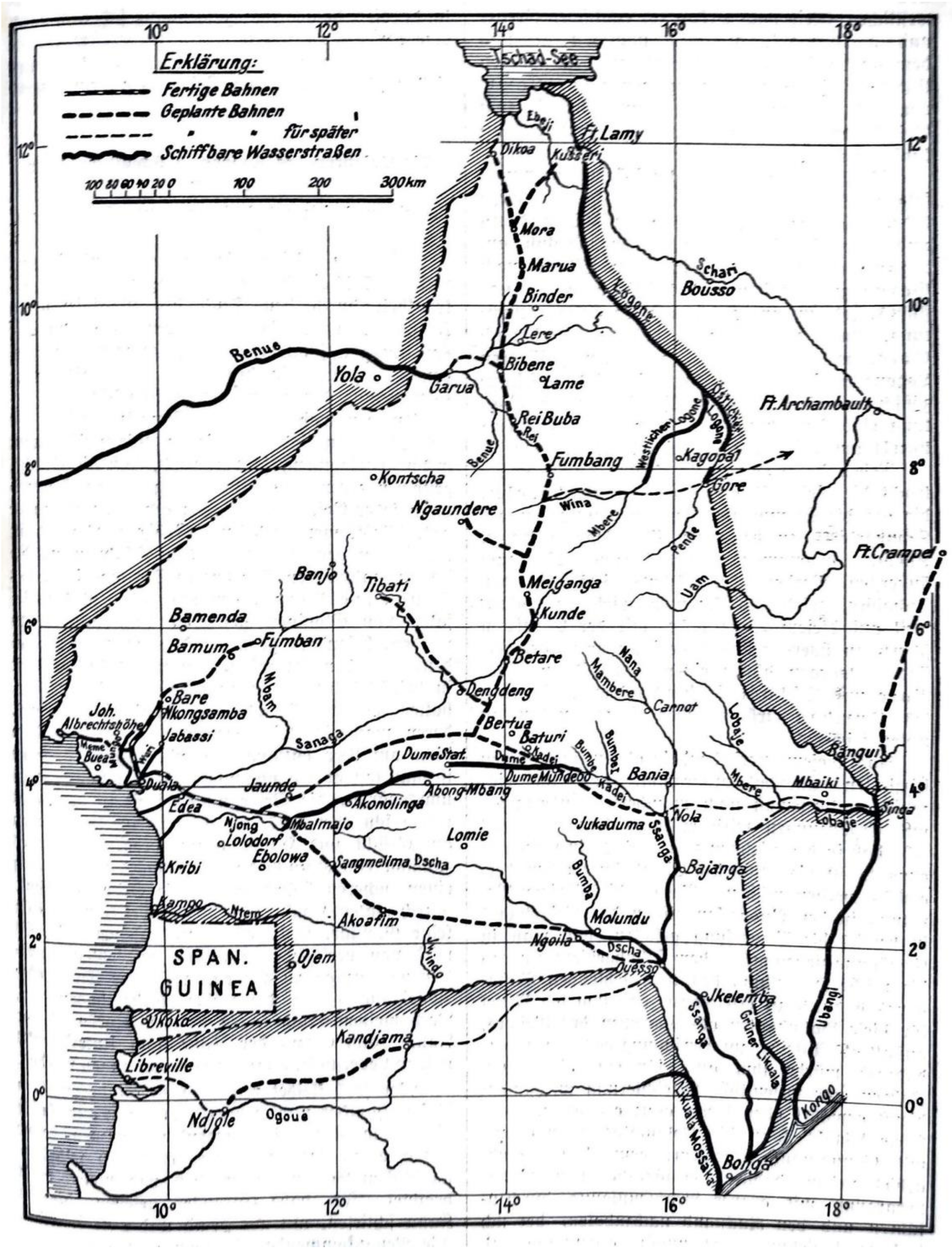

Figure 4.7. Rail projects and waterways executed and planned in Cameroon by the German Reich (Source: Deutsches Kolonialblatt, 1914)[22]

[22] Deutsches Kolonialblatt. Amtsblatt für die Schutzgebiete in Afrika und in Südsee . - Berlin : E.S. Mittler , 1914, pp. 502-506

The decision of setting in Douala the terminus of the second railway marked the destiny of the city as the main port and economic capital, and oriented for subsequent railway development. As can be seen in figure 4.7, Germany delineated an extension of the railway from Nkongsamba to Foumban but the choice was to reach the north using the route of the Mittellandbahn. In addition, this central line had to diverge in two other branches, one going southeast from Mbalmayo to the navigable Sangha River in Ouesso, and one going eastwards from Bertoua to Nola and Bangui. During this pre-war period ambitions were high and, had these plans been executed, all these lines would have added up to 3,000 km to Cameroon.

Indirectly, the Douala option also triggered the dawn of the road sector in Cameroon. During the German colonisation, Kribi still remained the first export port ahead of Douala, where half of the imports had already been directed thanks to the new transport facilities (US Department of Commerce, 1916)[23]. The chamber of commerce in Kribi felt discriminated against, notably because the Kribi-Yaoundé railway had been the very first option envisaged by Governor Puttkamer in 1895 (Rudin, 1938). These complaints coincided with the emergence of the automotive industry in Germany. The potential for a more flexible transport mode releasing an important mass of human-carriers that could work elsewhere turned the attention to the use of cars. It was in this way that the 286 km penetration road between Kribi and Yaoundé was built, as well as the link between Lolodorf and Ebolowa. Other shorter sections built at that time connected to urban centres close to the coast, like Edea and Buea, or were developed around trade areas in the west and the north. At the end of the German colony, 484 km of bridgeless roads practicable for motor vehicles were completed. However, with the existing technologies, road construction was as labour-intensive as the railway and had significant maintenance needs due to the rapid deterioration of earth roads in tropical weather. These works imposed an enormous burden on local populations, often mobilised through forced labour (Owona, 1996). As summarised in Table 4.2, according to Owona, the transport services during the German colony could be divided in 4 sub-systems:

	Destination	Mode	Exported goods
Congo basin	Congo river mouth	Steamboats	Rubber, ivory
South-coast	Kribi	Motor vehicle	Rubber
West-coast	Douala	Railway	Palm oil, coffee, cocoa, tobacco, timber
North	North Africa	Animal caravan	Grains, skins, cotton, herds

Table 4.2. Transport subsystems at the end of the German colony

[23] US Department of Commerce (1916). *Commerce Reports (Vol.1, Nos. 1-76)*, pp 685, Washington, Government Printing Office.

Upon their arrival in 1916, France and Britain administered respectively about four-fifths and one-fifth of the territory. In 1919, Cameroon was placed under the sovereignty of the League of Nations following the defeat of Germany in the First World War. As important as it was for the Germans, Cameroon had to become "the pivot of French policy in tropical Africa" (Sarraut, 1923). On the contrary, for the British, the Northern and the Southern Cameroons raised low interest, which resulted in little investment in infrastructure (Njoh, 2017). In addition, while "la mise en valeur" du Sarraut Plan introduced state planning and the economic unicity between the French colonies' and the metropole, the British "indirect rule" was based on the principle of self-sufficiency of the colonies, which meant that roads had to be mostly constructed with local funds (Nkwi, 2011). Therefore, until the Second World War, the road network in the British Cameroons benefited from few improvements or extensions and works greatly depended on cheap labour. Despite the aspirations of the Sarraut Plan, the initial two thirds of the French mandate also viewed a mediocre expansion of the transport network. In the early 1920s, when the bill was passed, French finances were under severe budgetary strain due to a poor economic outcome from the war (Gann, Duignan, & Turner, 1969). In fact, the Plan did not include the financial measures to execute it. Even so, this initial period of French mandate still involved important achievements in infrastructure development. It included the successive works in the port of Douala between 1922 and 1927[24], the arrival of the railway to Yaoundé in 1927[25], together with the branch to serve Mbalmayo on the bank of the Nyong River in 1933, and the about 1,000 km road link between Yaoundé and Garoua completed in 1930.

The aspirations of the Sarraut Plan continued to be pursued during the Great Depression. It still had little success. Faced with the withdrawal of the private sector, which until then had been the driving force behind the colonial economy, France decided to invest in economic infrastructure supposed to increase the profitability of its territories. This policy had to add revenues to the metropole, notably in the form of raw materials and agricultural products and facilitate an outlet for French manufactured products. The loans to finance these investments were supposed to be paid with the own resources generated by the colonies. However, maintenance and rehabilitation expenses had started to become a heavy burden and the expected profits, notably to be collected through customs, could not be raised in such a brief period. The burden of the debt fell on the local populations, almost entirely rural, which were heavily taxed. The result was a socio-economic crisis exacerbating the rural-urban exodus and the creation of what Coquery-Vidrovitch (1976) identified as "the vicious circle between aid and debts" that has typically characterised developing countries until present.

[24] Until 1922, the Port of Douala only had an 80-metre-long wharf as a berthing point for ships.

[25] The 120 km extension of the Central-Cameroon railway benefited from equipment left by the Germans as well as a quantity of earthworks already executed.

Despite its poor record, the Sarraut Plan exerted a considerable influence in the future development of the transport network in Cameroon (figure 4.8).

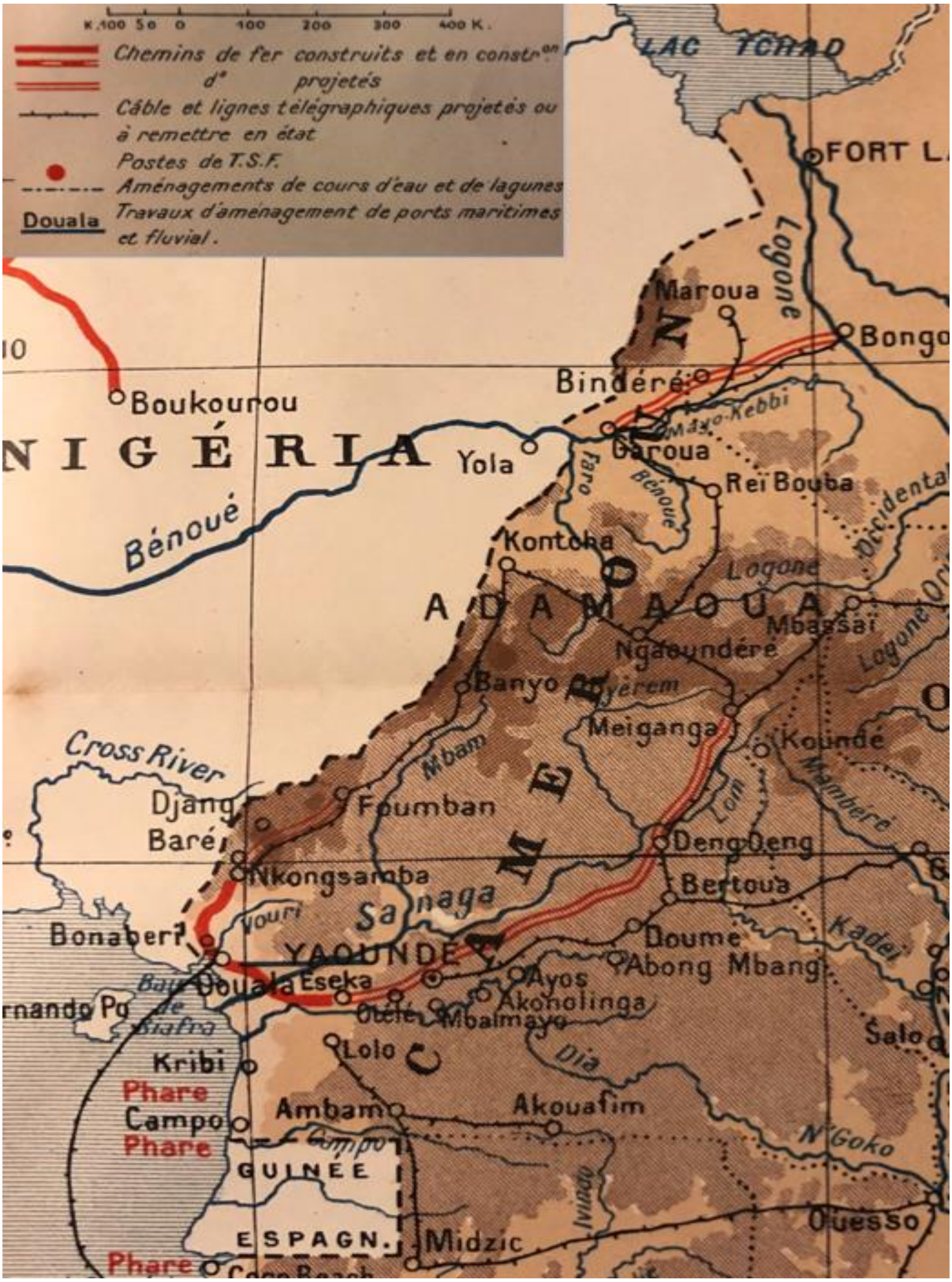

Figure 4.8. Railways planned in Cameroon in the Sarraut Plan (1923)

The document subscribed to German choices and clearly favoured one of the two penetration routes: the central railway linking Douala and Yaoundé and continuing northeast to reach the Adamaoua and the Lake Chad region. The reasons invoked against the North-Cameroon line were its "eccentricity", the relief in the area of Dschang and the low population density between Foumban and Tibati[26]. At the same time, it was acknowledged that the recommended eastern option would be longer and would also go through large low-density areas. The documents remain silent on the fact that the northern railway would have directly connected the three most populated areas in Cameroon: the Douala region, the western high grassfields and the Ngaoundéré-Garoua-Maroua region (see section 5.1). Neither the Sarraut Plan nor the Annual Reports of the Mandate refer to any economic study comparing the two alternatives (see map of period C2 in figure 4.21).

The decision to locate the capital in a more central position allowed for a better coverage and military control of the colony by displacing the activities' centre of gravity closer to the geographic centre, hence to the vast untapped forest areas in the southeast[27]. A decision equally geopolitical since it made Cameroon more accessible from the neighbouring Afrique Equatoriale Française. The choice of this penetration line was based on the administrative shape of the territory and was to a great extent the same reason that motivated, in 1921, the transfer of the capital to Yaoundé[28].

Interestingly, the idea of a railway linking Douala and the eastern parts of the French colonies, towards the Indian Ocean, was definitively abandoned at that time. For France, such a rail would make the port of Douala a serious competitor to the other French colonial ports in the Congo Basin. At the same time, French reports admitted that, by privileging the Central-Cameroon railway, they were losing the ability to counteract the influence from British Nigeria, a primordial objective when the Germans conceived the Nordbahn[29]. In 1931-1932, a mission conducted by Colonel Milhau carried out the engineering studies of the Centre-East route proposed by Sarraut. This study went even further and extended the planned railway into the south of Chad.

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[26] In addition to the Sarraut Plan (1923), see also the Rapport Annuel du Gouvernement Français sur l'administration sous mandat des territoires du Cameroun pour l'année 1922, p.114-115

[27] Journal officiel de la République française (1921), *Rapport au ministre des Colonies sur l'administration des territoires occupés du Cameroun. De la conquête au 1er juillet 1921*. Annexe - 21 Septembre 1921. p. 422

[28] Other reasons motivated the transfer of the capital to Yaoundé when Buea, the administrative centre under the Germans, fell under the control of the British Mandate: cool weather, absence of administrative buildings in Douala, etc. In fact, the Germans, before losing the territory, were already thinking of moving the capital to Yaoundé.

[29] Rapport Annuel du Gouvernement Français sur l'administration sous mandat des territoires du Cameroun pour l'année 1922, p.114-115

4.2.2. The FIDES era: big investments and late results (1946-1959)

In French Cameroon, it was not until 1939 that the first road asphalt works took place, with small projects executed in the Douala and Yaoundé urban areas and in the road going north from Douala to Nkongsamba (Franqueville, 1968; Ngoh, 1979). In addition, budgetary restrictions caused by the Second World War discontinued the operations. Asphalt works only resumed in 1949[30] in the context of the *Fonds d'Investissement pour le Développement Économique et Social des Territoires d'Outre Mer*, the "FIDES". Likewise, in the Cameroons under United Kingdom administration, the first road connecting the western highlands to the coast, from Kumba to Mamfe, was only completed in 1947, and road surfacing on the Victoria-Kumba section started in 1952[31].

The FIDES was an outcome of the Brazzaville Conference held in 1944, which prepared the post-war future of the French empire by reaffirming the ideal of "assimilation" of the colonies to France (Lewis, 1962). However, beyond the ideological considerations of generating prosperity in the colonies in order to treat all peoples associated with France on an equal footing, there was an explicit extractive interest that ushered in a new era of French investment policies in Africa. As stated by the President of the Imperial Economic Commission at the Brazzaville Conference (Atanagana, 2009):

> "This policy is not intended only for Africa. It also has the goal of facilitating the provisioning of the *métropole*. It is clear that France will need a considerable amount of raw materials and that African colonies will have to do their utmost to send them all the resources.
> This development policy does not pursue a purely African goal. It seeks as well to fulfil higher, more long-term goals to contribute to the recovery of the mother country."[32]

The FIDES was a fund to implement the *Plan décennal d'équipement économique et social des territoir d'outre-mer*, enacted by the French Parliament in 1946. Known as the FIDES plan, it was structured in two four-year programmes, 1949-1953 and 1953-1956. Overall, the underlying principles were in continuity with previous colonial policies: free movement of capital, extraction of raw materials in direction of the *métropole* and market expansion for French manufactured products. It represented a turning point to stimulate the economy of the French territories in Africa, since it envisaged a significant increase of public investment and incentives for French private industries to locate in the colonies (Atangana, 2009).

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[30] Blanchet, A. (1949). Premier besoin du territoire: des routes et de l'électricité. *Le Monde*, 10 octobre 1949.

[31] UN Trusteeship Council (1954), *Report on the Cameroons under United Kingdom administration submitted by the United Nations Visiting Mission to Trust Territories in West Africa*, 1952. p. 22

[32] ANSOM, affaires économiques 101, « Procès-verbal de la commission de l'économie impériale, 1er février 1944. »

Similarly, shortly after the end of the war, the United Kingdom Parliament adopted the third Colonial Development and Welfare Act 1945.[33] The financing available increased from £5 million per year in the 1940 Act to £120 million in the 1945 Act. It allocated to Nigeria about half of the estimated costs of the ten-year Plan of Development and Welfare (1946-1955). A four times bigger amount was allocated to a second five-year Nigerian Federal Government Development Plans (1955-1960).[34] Yet, at that time, the British colonial policy was significantly different from the French one. Successive reforms were preparing Nigeria to become an independent state within the British Commonwealth. In addition, the 1954 Constitution enshrined a federalist model that transferred powers to the regional governments, including the Southern Cameroons that became a separate quasi-Federal territory with its own legislation. Transport competences remained at federal level.

During the FIDES years, Cameroon was the territory that received more French public overseas investment: it benefited from nearly 17% of a total amount allocated to colonial possessions that today represent about twenty countries (Atangana, 2009). The investment per capita was on average 77% higher than in the other territories. On top of the economic and geostrategic interests, there were other motivations to favour Cameroon. France was accountable to the UN Trusteeship Council for the political, economic and social advancement in the Trust Territory. This external control did not exist with the other colonies, apart from Togo, also a trusteeship. In addition, in Cameroon, social discontent, emerging from the impoverishment of rural populations in the previous decade, was turning into political radicalization. Financial contributions were seen as a mean to neutralise it.

Two thirds of FIDES public funds went to transport and communications infrastructure. They were mostly allocated during the first four-year FIDES plan. Three quarters of the investments were concentrated in less than 6% of the territory, the region of Douala and the immediate neighbouring ones. As a result, despite the important investment, the expansion of the transport network was not significant. The most remarkable project was the 1,800 m rail-road bridge over the Wouri river, linking Douala and Bonaberi, which was crucial to make the railway system viable. Only this infrastructure absorbed about 11% of the total FIDES amount. Atangana concludes that France did not extend the network, and, in particular, the railway, because of the international status of Cameroon. It would have been too risky to invest beyond the immediate hinterland of Douala because Cameroon was not a full colony and there were growing independence movements. Therefore, the French would have preferred to invest only in the “fertile crescent”, l*e Cameroun utile* (Hugon, 1968), around Douala, where they could reap the highest profits.

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[33] Colonial Development and Welfare Bill. *Nature*. 155 (24 March 1945): 358–359. 1945. doi:10.1038/155358d0.

[34] Weeks, S., Macy, L.K., (1957). *Investment in Nigeria, basic information for United States businessmen*. US Department of Commerce

The gap between the official transport policy, framed in the FIDES Plan, and what was actually conducted should also be regarded from a transport engineering angle. The ambitious targets to cover all the territory were slowed down by soaring road maintenance needs caused by an exponential growth of the number of vehicles in Cameroon. The number of registered vehicles went from 5,074 in 1949 to 21,531 in 1955.[35] In particular, trucks carrying over 3 tons, many of them above 10 tons, increased from 2,632 to 7,977. The earth road network was not able to handle that heavy and intense traffic, especially in an environment of intense tropical rainfall. Overlay had become necessary to protect the roads with more traffic, notably, the ones entering in Douala (Roque, 1951). In just 5 years, Cameroon paved more than 500 km of roads.[36] In addition, to accommodate the new nature of the traffic, most of the roads needed important bridges to be built. In 1950, Cameroon had about 2,000 metres of bridges, but 3,150 metres more had been identified by the FIDES plan, leaving aside the one over Wouri. As a rule of thumb, nowadays, the asphalt wearing course and bridges represent an increase of 30-50% of the cost of an average modern African two-lane road, which explains the inability of the French to develop larger transport infrastructure with the available, and already significant, FIDES Plan budget.

Despite the relatively low expansion of the inland network, for the reasons we have described, it is important to analyse the long-term prospects of the FIDES plan and their possible influence on decision-making after independence in 1960. For Paul Darnault, the Director of Public Works in Cameroon between 1945 and 1951, besides asphalting and building permanent bridges, the urgency was to increase the connectivity of the territory (Darnault, 1951). Depending only on one penetration line was a matter of concern. In 1945, a railway bridge collapsed and interrupted the service for three months. Therefore, in addition the road-rail bridge over the Wouri River linking the two railway networks, the priorities for Darnault were the railway Douala – Chad and the two penetration roads Bonabéri – Foumban – Ngaoundéré – Garoua – Maroua[37] and Douala – Yaoundé – Bertoua – Bangui[38]. The first road was the alternative to the Nordbahn rail extension, a project that had been definitely abandoned by the French. Nevertheless, France still gave a high priority to this economic link and considered it as part of the Alger-Cape Town trans-African route. The second road had to be understood as the result of the review of the Milhau design of the Douala-Chad railway. When updating the studies, the financial situation of the railway in Cameroon had started to be critical. This was in part due to the harsh competition from road transport, which increased after the construction of a new paved road between Douala and Edéa (allowing it to continue towards Yaoundé on an

[35] Rapport Annuel du Gouvernement Français à l'Assemblée générale des Nations Unies sur l'administration du Cameroun placé sous tutelle de la France, Année 1955, p. 340-341

[36] It is also in this context that the first maintenance road fund was created in 1952.

[37] The road Douala-Ngaoundéré via Foumban was completed in 1954.

[38] Between Bertoua and Bangui, two itineraries were proposed, one going northeast passing by Betare-Oya and one going southeast by Batouri.

easier territory once the river system around Douala was overcome). For Darnault, there was a need to conciliate the use of the two modes, road and rail. Since there was already a parallel road to Yaoundé, the rail needed to be extended through areas where it could capture exportable goods and, thus, increase the ton/kilometre transported. Therefore, the Milhau project was updated with a new alignment at about 349 km from Yaoundé. At that point, the rail had to head straight north to pass through the bauxite deposits in Martap, then continue to Ngaoundére and finally turn east to reach Baibokoum in Chad, close to the border. Future extensions to the north and east of Chad were also envisaged.

In the end, the FIDES plan did not deliver the expected results in relation to France colonial policy objectives. In the beginning, between 1949 and 1953, the financial influx from the *métropole*, in the form of public works and engineering equipment, created jobs and boosted the economy (Atangana, 2009). However, in the medium term, these funds invested to modernise the infrastructure had no impact on the economy. The overall improvement of the transport had been significant but insufficient. Public policies were oriented towards an extractive economy where revenues depended on exports. The taxation system, necessary to repay the FIDES loans, represented a heavy burden for the local entrepreneurs. Private investment was further weakened by the uncertainty surrounding the CFA franc and growing social unrest and political instability. Even though the Second FIDES Plan was intended to increase agricultural productivity through cash crops, the economic impact could only be perceived by 1960. In the meantime, operating and maintenance costs sharply increased. New recurrent expenditure linked to FIDES investments represented one third of the territorial budget of 1956. Ultimately, France could not compensate with better economic conditions for the unremitting demands of an independent state.

In the British Cameroons, the last fifteen years before independence also witnessed the authorities' urgency to develop road infrastructure. Imbalances in living conditions were arising between both sides of the partitioned Cameroon. The impoverished border populations under UK administration were increasingly inclined to informally trade with French Cameroon and to travel along the roads at the other side of the border for longer distances (Nzume, 2004). This situation favoured pro-reunification movements (Amaazee, 1994). To counter this phenomenon, the British authorities embarked on a programme to improve connectivity between inland areas, in particular along the frontier, and the ports of Tiko and Victoria, as well as with the Eastern region of Nigeria. Several transversal east-west roads linking the border areas were planned along the major north-south trunk road Victoria-Kumba-Mamfe-Bamenda. A bridge over the Cross River connecting the Trust Territory and the Federation of Nigeria was built. The British Cameroons reached independence without the colonial authorities having been capable of reducing the infrastructure backlog accumulated since they took over from the Germans. In 1959, out of the about 1000 km of trunk roads existing in the Southern

Cameroons, only 135 had a bitumen surface. The Northern Cameroons did not have a single kilometre of asphalted roads.[39]

4.2.3. Sustaining independence's aspirations: the big infrastructure push (1960-1985)

The investment efforts initiated in the final colonial period, and the urge to make the new state viable, enabled a continued expansion of the transport infrastructure network during the first two decades of independence. In contrast with most of the former French colonies in Sub-Saharan Africa, Cameroon enjoyed considerable growth rates and a surplus balance of trade (Decraene, 1971; Atangana, 2009). A relatively good economic situation that, to some extent, could be attributed to the long-term positive impact of the FIDES, but also to the significant foreign aid that followed independence. Until 1963, France provided budgetary subsidies to support the growing operational expenses of the new administration (Bidias a Ngon, 1969), along with resources directly allocated to development projects through the Aid and Cooperation Fund (FAC). The European Development Fund (EDF), created by the Treaty of Rome in 1957, emanated from the FIDES and France had a considerable weight in it (Dimier, 2010). It was the second source of external funding in Cameroon, followed by the International Bank for Reconstruction and Development (IBRD), USA and Germany, which progressively increased their aid during the 1960s. Overall, as we have mentioned in the introduction, Cameroon received an above-average level of aid, in particular, from the EDF.[40]

It should be recalled that these investments took place in an international context marked by the developmentalism economic theories promoted by the United States during the Cold War and which, with the wave of secessionist processes in former European colonial territories, take on highly prominence. Indeed, while the United States supported the self-determination of these territories, it was necessary to offer an alternative economic development model to communism. These theories led, in the 1960s and 1970s, to the Big Push era of development economics, championed by influential economists such as Rostow (1959) and Rosenstein-Rodan (1961).

Until 1986, economic planning and resources allocation in Cameroon replicated the FIDES development model. Investments were identified and budgeted in five-year social and economic development plans. As the first "Plan Quinquennal" explains, at the time the country acceded to independence, the international aid system was not conceived to support economies like the Cameroonian. The IBRD, commonly known as the Word Bank,

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[39] *The Cameroons under United Kingdom Administration*. Report by Her Majesty's Government in the United Kingdom of Great Britain and Northern Ireland to the General Assembly of the United Nations for the year 1959

[40] According to the report "*Le Fonds Européen de Développement 1960-1975, Quinze années de coopération au développement*" published by the European Economic Community, Cameroon was the second aid recipient of the first EDF after Madagascar. Aggregating from the first to the third EDF, Cameroon was in third position after Madagascar and Senegal.

was lending at rates unbearable for the national budget and mainly to projects with direct financial profitability.[41] This is the reason why the Government of Cameroon decided to use loans almost exclusively in financing only one project: the Douala-Chad railway,[42] renamed as the Trans-Cameroon railway[43].

The decision to construct the Trans-Cameroon railway II was supported by a number of economic and political arguments already identified during the colonial times: opening areas with abundant raw materials (notably cotton, timber and bauxite), unlocking the northern populations, giving access to the sea to Chad and Central African Republic (CAR), increase the viability of the Douala-Yaoundé section, etc. Despite criticisms questioning the rail as a better option than the road (Hewitt, 1979), since its completion in 1974, the railway has played a vital role in unifying the north and the south of the country and, today, it is a profitable private concession in terms of freight transport.[44] In contrast, for Hewitt, the decision of constructing the Trans-Cameroon railway II deeply affected the pattern of aid allocation in the two decades that followed and reduced the capacity of the Government to invest in other transport infrastructure. While 87% of the total cost of the Trans-Cameroon railway, around FCFA 26 billion (Commission des Communautés Européennes, 1975), was borne by international aid,[45] the amount of the project contrasted with the budgetary revenues of the country, which in 1974/75 were FCFA 81.2 billion.[46] The railway absorbed almost one third of the first three EDF programmes, the second largest source of official development aid comparable to the one received from France. Moreover, it strongly determined the allocation of resources to the modernization and realignment of the Douala-Yaoundé section (Muñoz, 2022), a project that lasted almost as long as the extension Yaoundé-Ngaoundéré (1969-1986) and doubled the budget (FCFA 50 billion[47]; Dupré la Tour, 1998).

Focus on railway investment in Cameroon delayed road development at a time when, around the world, long-distance land transport was turning to roads. Cameroon went from about 750 km of asphalted roads in the early 1960s to 2,500 km in 1981, which

[41] In 1960, to respond to the reality of the new countries born in Africa with aid in the form of concessional loans, the Word Bank group created the International Development Agency (IDA).

[42] République du Cameroun (1961), Premier plan quinquennal de développement économique et social (1976-1981), ministère des Finances et du plan, p.20.

[43] The Trans-Cameroon railway I, or Transcam I, is the section Douala-Yaoundé, and the Trans-Cameroon railway II, or Transcam II, is the section Yaoundé-Ngaoundéré.

[44] Camrail (2019), Plan Stratégique 2019-2034, Bilan et perspectives

[45] The sources of funds for the Trans-Cameroon railway II were 54% grants (EDF and France), 33% loans (USA, the European Investment Bank and Germany) and 13% own resources.

[46] IVe Plan quinquennal de développement économique, social et culturel (1976-1981), ministère de l'Économie et du plan, République du Cameroun, p.67

[47] FCFA 50 billion in 1974 is about EUR 800 million in 2020. The Trans-Cameroon railway II is 662 km. Therefore, the construction costs were about 1.2M€ per kilometre.

represented less than 4% of the 65,000 km of identified road network.[48] Around 330 km of these overlying works were funded by the EDF (Commission des Communautés Européennes, 1989). France and Germany were also financing the improvement of some road sections, but the overall support remained meagre. The World Bank only started to finance road works from 1970, paying special attention to the improvement of the Trans-Cameroon road/rail route from the Ngaoundéré railway terminus towards the north. Roads linking the West (former British) and the East (former French) Cameroon were also prioritised during the first decade after independence. Thus, the "reunification road" Douala-Victoria and the Bamenda-Bafoussam section were paved during this period. Overall, the initial Five-Year Development Plans did not clearly establish an order of priority among the roads considered as important. The Government road policy was essentially favouring the connections to the Atlantic sea ports, with an evident focus on the Trans-Cameroon railway, and the roads contributing to national integration.[49] As identified by the Germans, the Douala-Bafoussam-Ngaoundéré road, named "national road no.2",[50] was still considered a major link to open up the north. In the 1970s and 1980s, the traffic to Foumban was the highest of the country, as shown in figures 4.9 and 4.10.

During the 1960s-1970s, new guiding principles were gradually integrated into transport planning in Cameroon. The location of the port of Douala continued, as still does today, to be a major element for decision-making in the transport sector. However, other considerations, mainly political, exerted a strong influence in prioritising the investments. Safeguarding the Trans-Cameroon railway from road competition was the first concern of the authorities. The Second Five-Year Development Plan (1966)[51] stated "*as the transport infrastructure is generally very onerous it will be necessary, if the case should arise, to take discriminatory and accessory measures to make the existing infrastructures as profitable as possible*". For instance, trucks transporting goods from the east and the south on those roads were not allowed to go until Douala for their exportation, but obliged to transfer their load to the train in Yaoundé (Cotten & Marguerat, 1977). This protection of the railway explains why the roads linking Yaoundé to Douala and Yaoundé to Ngaoundéré were only built in the 1980s. Until then, access to Yaoundé was difficult, with an ageing railway to Douala and just two paved major roads, one to Obala (40km) and one to Mbalmayo and Sangmelima (168 km). Dikoume (1982)

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[48] Ve Plan quinquennal de développement économique, social et culturel (1981-1986), ministère de l'Économie et du plan, République du Cameroun, p.XXIX

[49] World Bank (1970), *Appraisal of the First Highway Project, Cameroon*, Report No. PTR 33a.

[50] 1er Plan quinquennal de développement économique, social et culturel (1961-1965), ministère de l'Économie et du plan, République du Cameroun, p.192

[51] Federal Republic of Cameroon (1966), Second Five Year Plan of Economic and Social Development, Sector Annexes, p.319

calculated that 80% of the vehicles leaving Yaoundé were not going further than 60km from the capital.

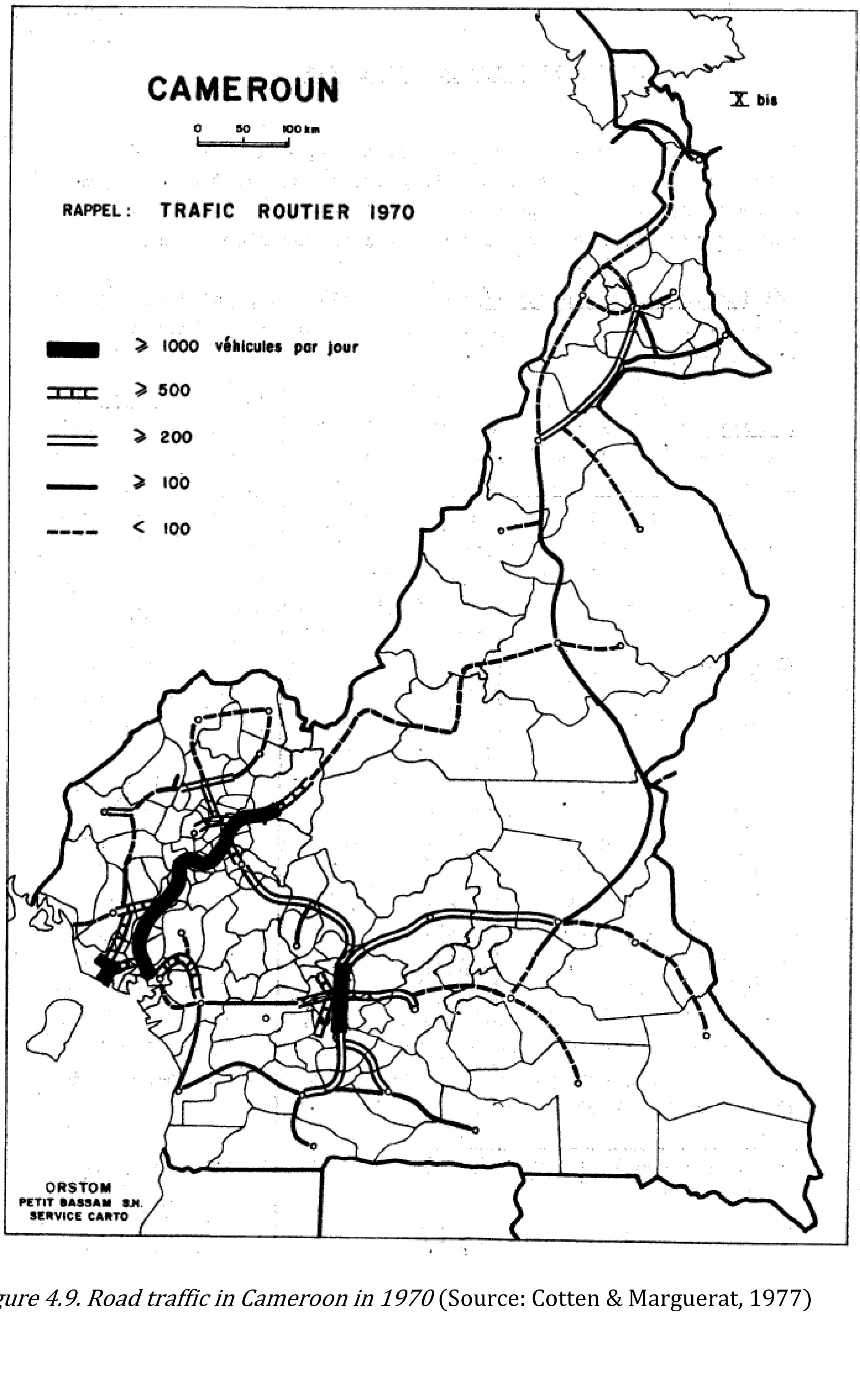

Figure 4.9. Road traffic in Cameroon in 1970 (Source: Cotten & Marguerat, 1977)

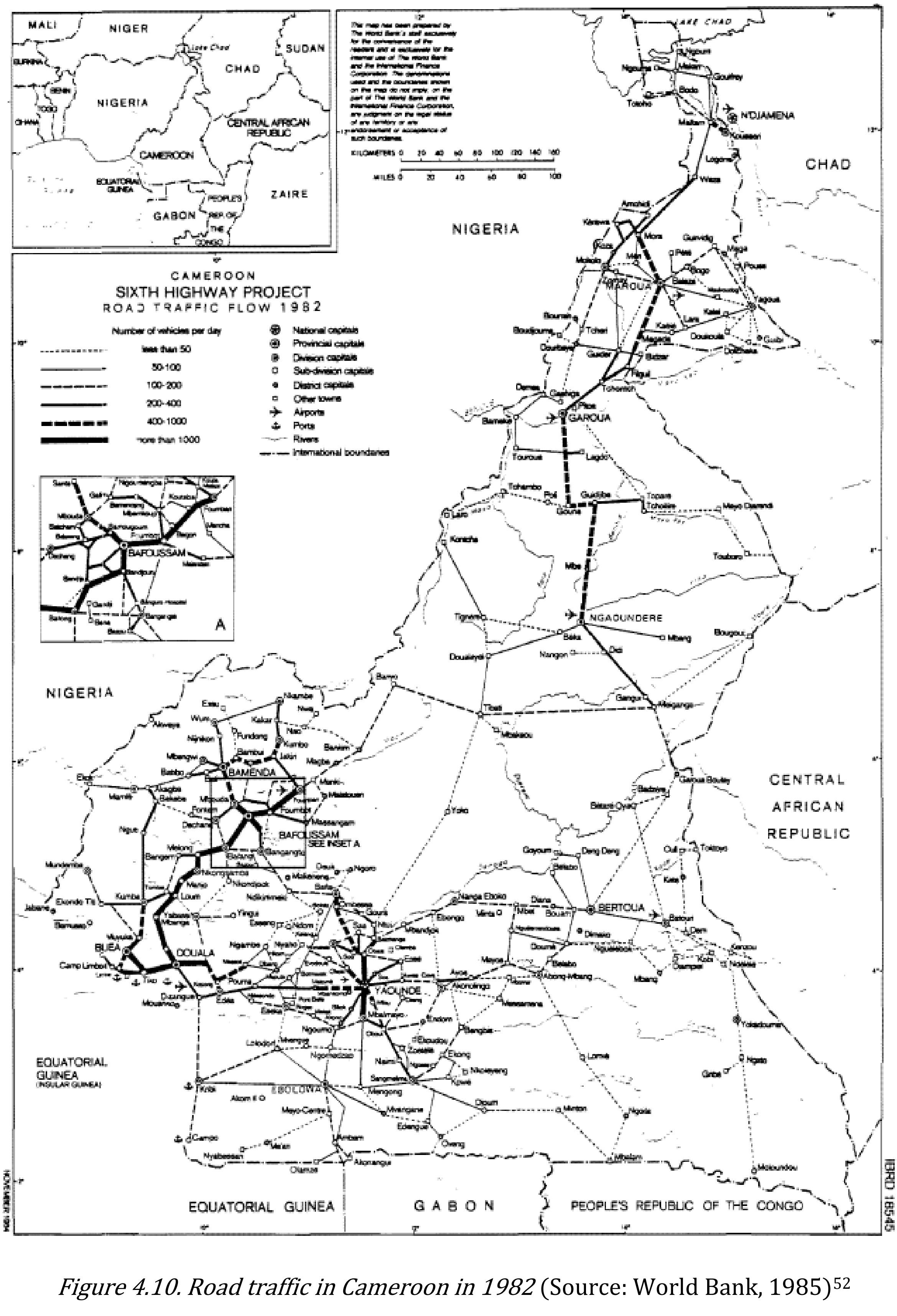

Figure 4.10. Road traffic in Cameroon in 1982 (Source: World Bank, 1985)[52]

[52] World Bank (1985), *Staff Appraisal Report of the Sixth Highway Project*, Republic of Cameroon, Report No. 5371-CM, p. 106.

The definition of the Trans-African Highways in 1971 had a considerable influence on decision-making. It coincided with Cameroon's active role in the pan-African institutions.[53] The first Trans-African Highway that was defined was the one from Lagos to Mombasa traversing Cameroon. In this context, the fourth "Plan quinquennal" (1976-1981) followed the notion of the Trans-African Highways and prioritised international links. However, these roads did not necessarily have an economic justification. Looking at the traffic of that time, as shown in figures 4.9 and 4.10[54], the section Tibati-Meidougou (237 km) of the Lagos-Mombasa Trans-African Highway that was built in Cameroon was far from being the project with the highest economic returns to the country. The construction of this road by COGEFAR, the contractor of the Trans-Cameroon railway, which intersected in Ngaoundal, close to an important quarry, illustrates another important factor directing public works in Cameroon: a prevailing collusion between an oligopoly of European construction firms and the political power (Owona Nguini, 1996). A system favoured thanks to EDF tendering rules of origin and nationality (Hewitt, 1979).

In 1972, the transformation of Cameroon from a Federation to a Unitarian State, represented a fundamental milestone in the concentration of power with a long-term impact on road development. As Raffestin (1980) would observe, the capital, Yaoundé, became the expression of the regime and symbolised the new political centrality. As a result, in a clear transposition of the French road network classification, infrastructure planning in Cameroon adopted in 1979 a radial capital-centred road system.[55] Yet, economic centrality remained in Douala. In this respect, the Fifth and last implemented Five-Year Plan (1981-1986) marked a notable change in the allocation of funding for the road sector. The railway to Ngaoundéré had been completed and the Douala-Yaoundé section rehabilitated. The contiguous road Ngaoundéré-Garoua-Maroua was almost finished thanks to considerable support from international donors. The priority of the government of Paul Biya, who succeeded Ahidjo in 1982, was connecting Yaoundé with the two other main cities of the country, Douala and Bafoussam. These two roads only, about 530 km, represented one third of the budget for roads and bridges of the fifth "Plan quinquennal". The notion of trans-African highways had virtually disappeared from the document. In terms of network configuration, the commissioning in 1982 of the 1km bridge over the Sanaga River at Ebebda, constituted a major milestone in completing the Douala-Yaoundé-Bafoussam road triangle. Because of this road and the Trans-Cameroon railway, the National Road N°1 through Batschenga and Yoko, built during colonisation and that was for a long time the main communication route linking the south to the

[53] President Ahmadou Ahidjo was the Chairperson of the Organisation of African Unity between September 1969 and September 1970. Later, Nzo Ekangaki, a Cameroonian, served as the Secretary-General from 1972 to 1974.

[54] Even the traffic existing in 2013 was still extremely low according to the traffic counts by the Ministry of Public Works.

[55] In 1979, the national roads were renumbered and the four first numbers were given to roads originating in Yaoundé (N1: Yaoundé-Bertoua-Maroua, N2: Yaoundé-Gabon, N3: Yaoundé-Douala and N4: Yaoundé-Bafoussam). Presidential Decree no. 79/093 of 21 March 1979.

northern part of the country, and the essential stage for travelling to Chad or the Central African Republic, fell into disuse.

4.2.4. A painful awakening: the structural adjustment programmes (1986-2004)

The sixth Five-Year Development Plan was stillborn. In previous years, Cameroon's economy had suffered a prolonged fall in the prices of the main export products, a strong appreciation of the CFA franc against the dollar and the depreciation of the Nigerian naira. From 1985-86, Cameroon entered a ten-year recessive spiral of falling export earnings and public revenue, a reduction in public investment, an explosion in debt servicing, the generalisation of questionable debts and cross-debt, the illiquidity of the public treasury and the banking system, and a reduction in domestic demand. In 1988, Cameroon had no other choice than to accept the structural adjustment programmes (SAPs) required by the donor community. However, it was not until the years following the 1994 CFA Franc devaluation that the IMF could consider Cameroon "on-track".

Ruinous public investments in the transport sector contributed to the economic crisis. The costly realignment of the Douala-Yaoundé railway had generated significant debt with a variety of creditors ranging from the German development bank (Kreditanstalt für Wiederaufbau, KfW) to the African Development Bank (AfDB). In addition, the 245 km road between the two cities, constructed from 1982 to 1988, resulted in an exorbitant cost. Announced as a four-lane expressway, the project was finally executed as a two-lane untolled paved road. The World Bank had played an active role in persuading the Government to opt for this simplified alternative and to add two further lanes at a later stage. The financing institution had advanced low traffic demand forecasts and insisted on the need to maximise the development impact across the areas surrounding the road (which could not be achieved if the highway was tolled).[56] This disagreement had resulted in a disengagement from the World Bank in supervising some sections of the project, leaving the Government directly implementing the project without donor's involvement. At the end, the average per km project cost was US$2.29 M (US$4.6 M for the Douala-Edea section and US$1.6 M for the Edea-Yaoundé section supervised by the World Bank).[57] These per km costs are higher than the average cost of a new two-lane road in Africa at 2018 prices (US$1.76 M/km) and closer to the cost of a multiple lane motorway.[58] An outrageous cost that cannot only be explained by the technical specifications adopted (asphalt base course) and the difficult landscape. Euphemistically the resulting road was called "axe lourd" (heavy link), even in official documents. The two

[56] World Bank (1991), *Project Completion Report of the Fifth Highway Project (Loan 2180-CM)*, Republic of Cameroon, Report No. 9866, p. 2

[57] Ibid, p. 17

[58] Road Costs Knowledge System (ROCKS) https://www.doingbusiness.org/en/reports/thematic-reports/road-costs-knowledge-system

additional lanes were never constructed.[59] In addition, the number of deaths due to road accidents must be added to the economic cost. In the 2000s, with an estimated overall number of 73 people killed in road crashes per 100 million kilometres driven, more than 35 times higher than on similar roads in the US or Europe (Sobngwi-Tambekou, 2010), it became one of the "most dangerous roads in the world"[60].

In Cameroon, as in many other countries in Sub-Saharan Africa in the 1990s, the SAPs translated into a Transport Sector Project (TSP) led by the World Bank. Donor's participation in transport investments was drastically reduced and aid focused on supporting sector reforms. The objectives pursued by these reforms were clearly aligned with the SAPs goals: "state divestiture from transport operations in favour of a greater involvement of private operators, and institutions more focused on planning, regulation and definition of sector policies; better balance in resource allocation between prudent investments and maintenance expenditures, and sustainable resource mobilisation; improved regulatory framework resulting in more liberalisation, increased competitiveness and more competition".[61] As far as land transport is concerned, it is worth noting several major reforms that have lasted until today. The *Régie nationale des chemins de fer du Cameroun*, abbreviated as «Regifercam», which had been operating the railway since 1947, was privatised in 1999 and conceded to the company Camrail, owned by the French firm Bolloré (77.4 %). In the road sector, the main results of the TSP were in the areas of asset protection and maintenance. The laws enforcing weight control and creating the Road Fund were adopted in 1996 and 1998 respectively. Road maintenance works were opened to private enterprises.

In terms of network development, the European Union, the AfDB and the Agence Française de Développement (AFD) financed the only significant road works conducted during the 1990s. These sections had been studied during the Fifth Five-Year Development plan, which still considered two options to reach the north of the country by road: the national road no. 6, Bafoussam-Foumban-Tibati, and the national roads no. 10 and 1 via Ayos-Abong Mbang-Bertoua-Garoua Boulai-Meidougou.[62] The section Bafoussam-Foumban was financed by the AfDB and completed in 1996. The 126 km between Yaoundé and Ayos, as well as the Akonolinga slip road, with a length of 12 km

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[59] In 2019-2010, some short sections, where road accidents were particularly serious, were widened to three lanes and upgraded with support from the European Union.

[60] Mbadi, O. (2015), *Cameroun : Douala-Yaoundé par la nationale 3, l'axe du mal*, Jeune Afrique, 17 mai 2015, https://www.jeuneafrique.com/231702/politique/cameroun-douala-yaound-par-la-nationale-3-l-axe-du-mal/

[61] World Bank (2004), *Implementation Completion Report of the Transport Sector Project (IDA-28690)*, Republic of Cameroon, Report No. 28057-CM, p. 3.

[62] Between Yaoundé and Bertoua, the national road 10 was preferred to the no. 1 because the latter would have represented a serious competition for the rail as both follow the same alignment.

were built between 1991 and 1994 using EDF funds.[63] Regarding the rail, following the privatisation in 1999, the sections Mbanga-Nkongsamba and Otélé-Mbalmayo were dismantled due to their low profitability. The train services to Nkongsamba had already stopped in 1991. Only the line Mbanga-Kumba operates for political reasons, as a symbol of unity between the Anglophone and the Francophone Cameroons and, for its maintenance, the section Bonaberi-Mbanga has been kept.

The fragility of the state made road planning in Cameroon dependent on donor preferences. Thus, the decisions on these few investments in the 1990s followed to a great extent the advice given by aid-funded technical assistants who "tried to optimise the scarce financial resources available".[64] The European Economic Community (EEC) had, since the late 1980s, a growing interest in supporting regional integration to catalyse economic development and promote peace.[65] As a result, the EEC played a fundamental role in supporting the *Union Douanière et Économique de l'Afrique Centrale* (UDEAC) in defining the regional transport itineraries. The 1993 regional act[66] opted to prioritise the link between Cameroon and the Central African Republic (CAR) along the road Bertoua-Garoua Boulai instead of the road Bertoua-Kenzou (figure 4.11). Although, as planned in colonial times, the road through Kenzou was the shortest way to reach Bangui, the construction of the section in CAR, where it is called "road of the 4th parallel" (*route du 4ème parallèle*), traversed the dense tropical forest and would have implied a high environmental impact. In addition, by deviating to the north, the northern and southern paved road networks in Cameroon were closer to be joined. The road Bertoua-Garoua Boulai was constructed between 1999 and 2002.

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[63] While the 6th EDF (1986-1990) was the first one not having an envelope for the transport sector in Cameroon, the EEC opted to support the construction of the Yaoundé-Ayos road by aggregating the unconsumed funds from the 4th, 5th and 6th EDF.

[64] 15/09/2020: interview with Jean-Marc Gauthier, coordinator of EDF-financed regional road projects in Central Africa between 1995 and 2003.

[65] See, for instance the issue No. 112 (November-December 1988) of The Courier, the bulletin of the EEC-ACP cooperation, titled "Regional Cooperation".

[66] Acte n°9 93-UDEAC-556-CD-SE1 du 21 juin 1993 approuvant les Itinéraires structurants de transit pour la mise en place de la procédure de Transit Inter-États des Pays d'Afrique Centrale (T.I.P.A.C.).

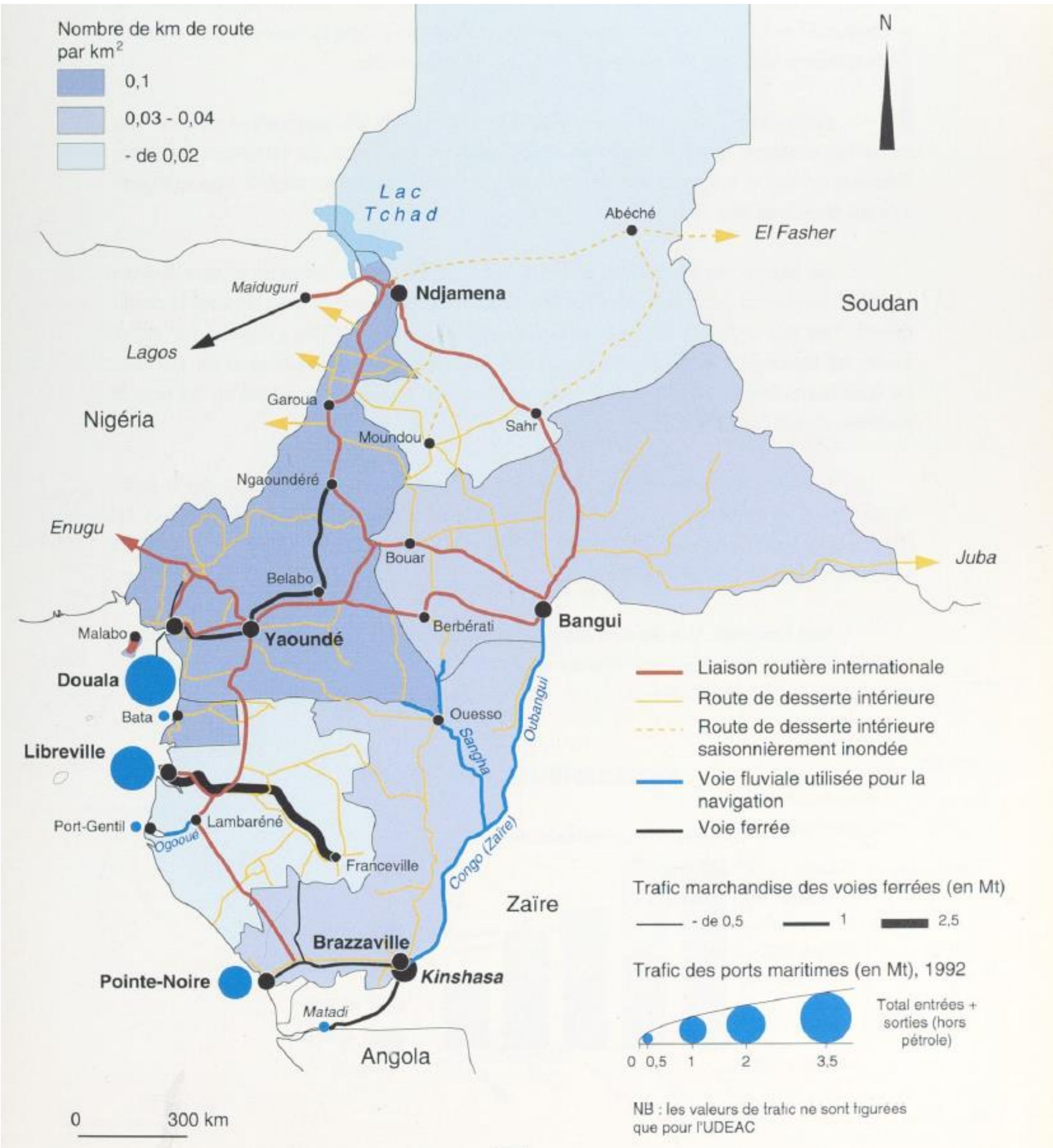

Figure 4.11. Transport routes planned in the UDEAC zone in 1993 [67] (Source: UDEAC)

Donors were also heavily involved in developing the road linking Yaoundé with Gabon and Equatorial Guinea. From 1988 to 1991, the AfDB financed the construction of the road Mbalmayo-Ebolowa and the section Ebolowa-Ambam was built with AFD funding. In this context, another major decision affecting the network was made in 1994 when, in accordance with a regional complementary act,[68] it was agreed to build two bridges over the Ntem river in the south of Cameroon. They were both along the national road No. 2

[67] Pourtier, R. (1993). *Atlas de l'UDEAC.*, ministère de la Coopération, Paris.

[68] Acte nº7 94-UDEAC-556-CE-30 complétant l'Acte nº93-UDEAC-556-CD-SE1 du 21 juin 1993 approuvant les Itinéraires structurants de transit.

connecting Yaoundé with Gabon and Equatorial Guinea. With the construction of two bridges, the road forks in Ambam, at about 30 km from the borders, so that one way, which was financed by the AfDB, goes to Gabon and the other, financed by the AFD, to Equatorial Guinea (See figure 4.12). The bridges were financed by the EU and completed in 2005.

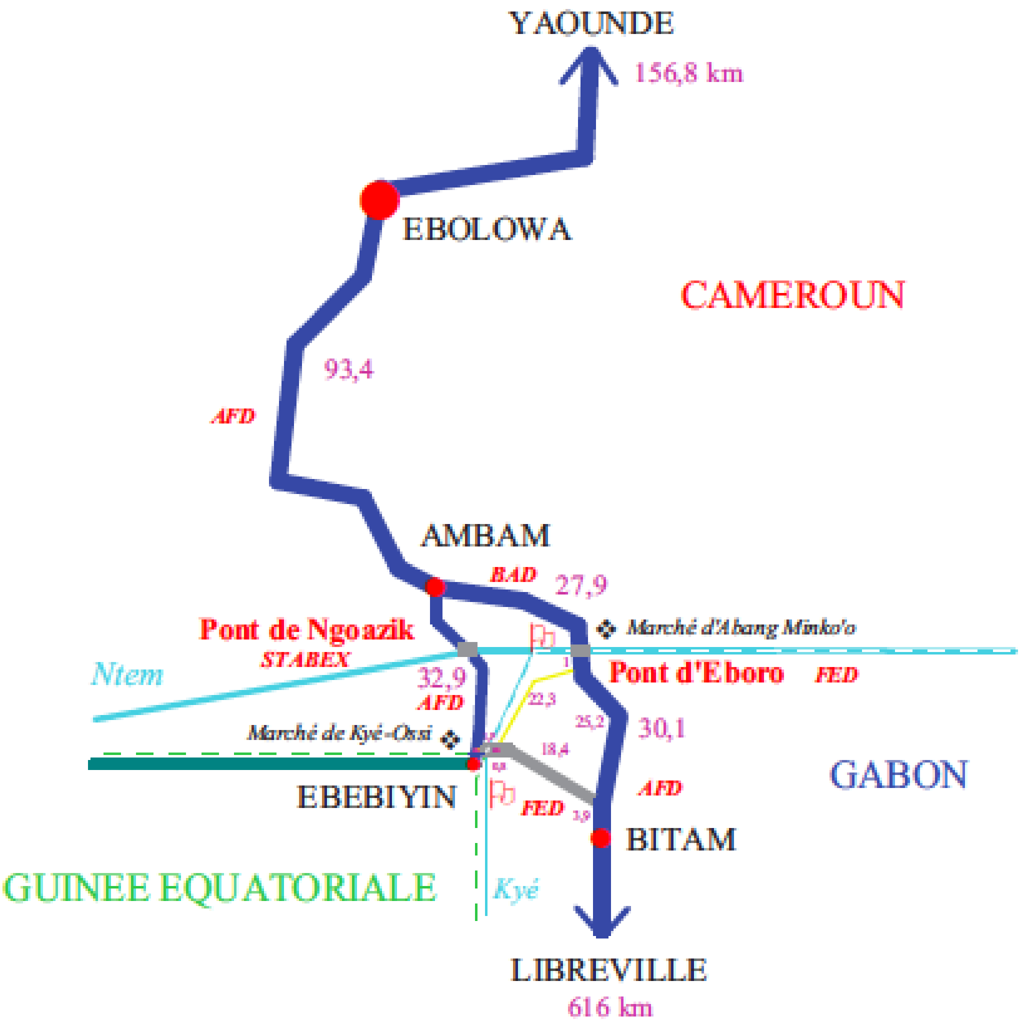

Figure 4.12. General outline of the national road No. 2 in the south of Cameroon (Source: Gauthier, 2002)

4.2.5. Reaping the benefits of debt relief: will the returns come in time? (2005-2015)

In October 2000, Cameroon joined the Heavily Indebted Poor Countries (HIPC) Initiative, which, led by the IMF, had to involve substantial and collective donor support conditional on strict control on public spending and policy reforms. The completion point of the HIPC initiative could only be attained in April 2006. In addition to many cooperation instruments already available, the HIPC completion point allowed major creditors like France to reinvest in public aid the sums from debt repaid by Cameroon. More importantly, it restored a climate of trust with financial institutions. During the period 2004-2007, the transport sector accounted for 15% of GDP and 59% of transport-related investments were financed by external partners.[69] From 2006, loans to the road sector from both the World Bank and the AfDB resumed, and amounts increased sharply. More than 60% of the grants from the 9th EDF (2001-2007) and the 10th EDF (2008-2013) were allocated to road infrastructure. From 2006 to 2010, all these three donors together allocated about one billion Euros to the road sector. The *Agence Française de Développement* (AFD) and Arab financial institutions were other donors providing significant resources to the sector.

During the 2000s, Cameroon's transport sector remained highly conditioned by donors' requirements in terms of both policy and investment choices. The reforms initiated during the PST, now set out under a public works sector strategy, were one of the triggers for the completion point of the HIPC initiative. In the period preceding the completion point, the European Union (EU) became a prominent donor because Cameroon could not easily obtain loans from development banks and the EU funding is primarily based on non-reimbursable aid. The EU-funded technical assistance deployed since the 1990s was providing remarkable results. The progress made towards the enforcement of axle-load regulations was to a great extent boosted by the pressure exerted by the EU Delegation in reaction to the premature degradation of the Yaoundé-Ayos road.[70] Thus, in 2004, with the completion of the PST, and in the absence of a new strategy, the EU and the Government decided, in consultation with development partners, to draw up a Memorandum of Understanding (MoU). The MoU's purpose was "to summarise the intentions, commitments and measures proposed by the Government to preserve the achievements of the PST, to accelerate progress on certain commitments made earlier and to improve the effectiveness of the sector's performance".[71] This MoU was later revised in 2006 and 2009 and remained for the international community a strong road sector overseeing instrument.

In 2006, Cameroon formulated a Road Master Plan[72]. However, given that the new donor paradigm was regional economic integration (Oliete Josa & Magrinya 2018), the priority sections that were finally implemented were those supported by foreign aid, which hoped to facilitate trade with neighbouring countries.[73] The roads from Garoua-Boulai to

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[69] African Development Fund (2009), *Batchenga-Ngaoundéré Road Study*, Memorandum of the study, p. 2.

[70] 15/09/2020: interview with Jean-Marc Gauthier, coordinator of EDF-financed regional road projects in Central Africa between 1995 and 2003.

[71] Ministère de l'Économie et des Finances/Ministère des Travaux Publics (2006), Memorandum of Understanding sur la réforme et le financement du sous-secteur routier au Cameroun révisé.

[72] Ministère des Travaux Publics (2006), Plan Directeur Routier du Cameroun, study carried out by the Italian consultancy firm AIC PROGETTI and funded by the EU.

[73] This objective was explicitly reflected in the title of the World Bank project "CEMAC - Transport and Transit Facilitation" and the AfDB's "CEMAC - Programme De Facilitation Du Transport Sur Les Corridors Douala/Bangui et Douala/Ndjamena".

Ngaoundéré, connecting the north and the south of the country by an asphalted road, and from Ngaoundéré to Moundou (Chad) were among the prioritised regional new links supported by development partners. In addition, the creation of the African Union (AU) in 2002, replacing the Organisation of African Unity (OAU), renewed Pan-African ideals and revitalised the 1970s aspirations of interconnecting the continent through a network of Trans-African Highways. This new impetus was crystallised in the New Partnership for Africa's Development (NEPAD), an AU economic development programme that aimed "to provide an overarching vision and policy framework for accelerating economic co-operation and integration among African countries". In this context, the AfDB, although its governance is independent from the AU, received the mandate to implement the NEPAD infrastructure initiatives and later became the lead "executing agency" for the Programme for Infrastructure Development in Africa (PIDA) that succeeded the NEPAD.

In this context, the AfDB in Cameroon decided to support two multinational projects not opening landlocked countries: the Bamenda (Cameroon)-Enugu (Nigeria) road along the Lagos-Mombasa Trans-African Highway and the Ketta (Congo)-Djoum(Cameroon) linking Yaoundé and Brazzaville. In those years, the only significant project financed by donors looking at the internal network was the rehabilitation of the road Buea-Kumba-Mamfe, the backbone of the Anglophone regions, as the British had established. The resulting investments diverged considerably from the scenarios envisaged in the 2006 Master Plan, in particular with regard to the busiest itineraries: the Ngaoundéré-Garoua-Maroua-Kousseri route, built in the 1970s, which was seriously deteriorated and needed urgent rehabilitation, and the exit/access roads and bypasses of major cities and the roads linking the three main urban centres: Yaoundé, Douala and Bafoussam.

In 2010, encouraged by good economic prospects and oil prices, Cameroon raised its development ambitions by announcing a programme for economic emergence by 2035.[74] This emergence rhetoric heavily embedded official documents, in particular, the 2010-2020 Strategic Document for Growth and Jobs (*Document Stratégique de Croissance et d'Emploi-DSCE*).[75] In this context, the total public sector debt in Cameroon increased threefold between 2010 and 2016, reaching 35.2% of GDP.[76] For the transport sector, the DSCE did not set quantitative targets in terms of road network coverage but in relation to the quality of service. In this respect, the objective was to increase the proportion of the asphalted road network from 10% to 17% by 2020 and the road network in good condition up to 55%. It represented the asphalting of an average of 350 km of roads per

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[74] Republic of Cameroon (2008), Vision Cameroun 2035

[75] The DSCE is a direct successor of the Poverty Reduction Strategy Paper (PRSP) 2003-2010. The formulation of PRSPs were promoted by the World Bank and the International Monetary Fund as the foundation for their lending programmes and for debt relief for Heavily Indebted Poor Countries (HIPCs).

[76] International Monetary Fund (2017), *Cameroon. Request for a Three-Year Arrangement under the Extended Credit Facility - Debt sustainability Analysis* https://www.imf.org/external/pubs/ft/dsa/pdf/2017/dsacr17185.pdf

year.[77] This approach to road planning could be introduced in 2010 thanks to the Road Geographical Reference System of Cameroon, a digital mapping and coding of the entire primary and secondary road network.[78] However, despite some minor references to a Road Master Plan, probably the one of 2006, and to a railway master plan under preparation, the orientations of the DSCE in terms of investment priorities in the transport sector remained vague. Under the DSCE, the Government launched several major projects or "*projects structurants*",[79] some of which were in the transport sector: the Kribi port complex, the Wouri second bridge, the Yaoundé-Douala highway and the construction of 1,000 kilometres of railway. At the same time, the document highlighted some missing links in the network, such as the corridor north-south from Garoua-Boulai to Ngaoundéré, but, in general, the DSCE was silent on other important projects decided during the decade.

Regarding those investments not explicitly mentioned by the DSCE, it is worth highlighting two main trends. On the one side, the reinforcement of Yaoundé as central node of the network, in particular through the projects Yaoundé-Ntui-Yoko-Ngaoundéré, Yaoundé-Mbalmayo-Sangmelima-Ouesso(Congo) and Yaoundé-Lolodorf-Kribi. The link between Yaoundé and Ngaoundéré via Ntui and Yoko is particularly striking, as it was prioritised instead of the historical link Foumban-Tibati and while the east road via Garoua-Boulai had just been completed. Justified as the shortest way between the capital and the north of the country, it had remained practically under the same standards since the French built it in the 1920s because it passes through areas of low population density. The other remarkable feature is the increase of investments in urban transport infrastructure in the main cities, notably in Douala. This choice was to a great extent encouraged by France, using funds from debt relief and AFD loans. Hosting the Football African Cup of Nations (AFCON) was also a stimulus to invest in cities[80].

From mid-2014, economic indicators in Cameroon started to decline. In addition to a sudden drop of the world oil prices, the security situation deteriorated along the country borders with Nigeria and CAR, which raised unexpected military expenses. At the same time, the preparation of the AFCON was absorbing significant public resources. Confronted with the incipient economic crisis, the Government launched the 2015-2018 Triennial Emergency Plan. Funds were raised from commercial banks and from the

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[77] Republic of Cameroon (2009), Growth and Employment Strategy Paper. Reference framework for Government action in the period 2010-2020

[78] Financed by the EDF and French debt relief funds, this geographic information system is better known by its name in French: *Référentiel Géographique Routier du Cameroun*.

[79] According to the Cameroonian authorities, "a major project is a project whose investment cost represents, at least, 1 percent of the annual budget spending, and which sustains long-term growth development perspectives through positive, important and persistent spillover effects on innovation, employment and intersectoral economic activity". IMF Country Report No. 20/48

[80] Cameroon was initially entrusted to host the 2019 AFCON edition. However, the preparatory work was not ready on time and the event was organised in Egypt. Cameroon hosted the 2022 edition.

financial markets. However, the economy was further declining due to the CFA Franc monetary union of Cameroon with its oil-dependent neighbours and to the armed conflict with separatists' groups that broke out in the Anglophone regions. Under these circumstances, Cameroon did not have any other choice than to accept, in 2017, an IMF-supported programme conditional on reforms to control public debt. From 2018, Cameroon's economic development slowdown aggravated with two additional crises. First, an unprecedented political turmoil following the 2018 Presidential elections, and, in 2020, the COVID-19 pandemic.

While the economic returns of the DSCE were expected over the long-term, in many cases, the investments accumulated enormous delays. The capacity of the Government to accelerate their implementation was greatly reduced, not only for financial reasons, but also due to the trap that represented some failed major projects. The Kribi port complex was first delayed several years during the works phase and then, its operationalization took off too slowly because the project did not plan in advance critical enhancing infrastructure such as the access roads and railways. The Yaoundé-Nsimalen Airport highway lacked adequate planification and remained uncompleted along the urban areas. The most problematic case was the Yaoundé-Douala Highway. In 2013, after having rejected EU funds to conduct the studies, the Government launched the project under an opaque design and build scheme with Chinese funding. In 2020, the first 60 km of the about 218-km highway were not delivered yet. Environmental and social impact remains unclear. According to the main business organisation in the country, the GICAM, between 2010 and 2020, the Cameroonian government only achieved 65% of its objective of asphalting 3,500 km of roads, which corresponds to 2,274 km of paved roads.[81]

[81] https://www.investiraucameroun.com/travaux-publics/3011-15651-bitumage-des-routes-le-gicam-trouve-les-ambitions-du-cameroun-sur-la-prochaine-decennie-irrealistes

4.3. Economic activities and characterisation of the network

As explained in section 3.2.3, the maps of years 1930, 1955, 1966, 1966, 1978, 1995, 2005, 2015 have been digitised and characterised in detail. The 1930 map is considered to be the first one in which the entire country can be traversed along a road suitable for motorised vehicles (albeit by crossing the waterways in barges). It is also the time shortly after the railway to Yaoundé was completed and the time when river transport began to decline (with exceptions such as the Benué River, a tributary of the Niger). In the following sections, the analysis of each of the maps begins with a brief description of the main economic activities in Cameroon, to better understand the flows of goods transport during those years. It also explains the characteristics of the network and the main changes from one map to the next, as well as the projects implemented in each period.

4.3.1. The transport network in Cameroon in 1930

In the 1920s and 1930s, Cameroon's economy was essentially based on the export of its forest resources and the products grown on its plantations[82]. Despite the potential for mining, given what was being extracted in the neighbouring colonies, the mining industry had not yet started to develop and there were hardly any geological studies. On the other hand, thanks to its agro-ecological diversity (see figure 4.5), the Cameroonian territory offered a large quantity of products for internal consumption or export. In the northern savannahs, livestock farming was predominant. Shea butter was also produced in the Adamaoua region. The main product obtained from the eastern forests was rubber, although timber and fibres such as raffia and rattan were also extracted. In contrast, in the central and coastal forests, the main agricultural product was palm kernels, which was the main export product, also traded as processed palm oil. In the central and western regions, food crops were developed for both local and European populations. Cocoa was also grown in the west region but, in terms of total exports, its production was much lower than that of palm oil and timber.

1930 is the year the road between Yaoundé and Garoua via Yoko was completed, hence connecting the north and the south of the country (figure 4.13). The railway between Douala and Yaoundé had recently started to operate as well (end of 1927). However, as we can see in the map, the transport system consisted of different disconnected networks, or at least not linked by motor roads or rails. The eastern part of the country was still, for the most part, not covered by the transport system and just two roads from Doumé and from Lomié were feeding the port of Abong Mbang, on the Nyong River. This river was navigable for small steamers and light oil-powered vessels along 250 km. It was used to transport rubber and palm oil to Mbalmayo, the end of the spur track linked to the main Douala-Yaoundé railway.

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[82] Commissariat de la République Française au Cameroun, 1927, Guide de la colonisation au Cameroun, Paris, Librairie Emile Larose, pp. 37

Figure 4.13. Road and rail transport network in Cameroon in 1930 (Source: Author)

River transport has not been included in this study because it is only in the 1930 map that it was still a relevant mode. Even at that time, inland waterways were considered as “mediocre” by the colonial powers[82]. Some of the rivers in Cameroon were accessible to small coastal steamers. The Sanaga, one of the most important rivers in Cameroon, receives many tributaries and is navigable only on an 80-kilometre stretch from the sea to Edéa. The Mungo, which limited the border between the British and French territories, was navigable in all seasons up to Manga Beach, 120 km from its mouth. From Douala, the Wouri and the Dibamba rivers were navigable up to 60-65 km. The above-mentioned Nyong was navigable along 60 km in its downstream coastal part. The Campo River, also called Ntem, was navigable up to 40 kilometres from the coast. In addition, Cameroon has numerous creeks, which go deep into the land and increase the number of navigable routes. Inland, the number of navigable rivers was of little importance. In addition to the Nyong, the Dja in the south and the Logone in the north were used by small steamers. The only major river used by big steamers was the Benué. From Garoua, during 5 months per year, this river could be used to transport goods to and from the Atlantic Ocean, linking up with the Niger via neighbouring Nigeria.

The other disconnected part of the network was the British Cameroons. In the map, we can observe that it was essentially a backbone road penetrating from the coast. One of the main drawbacks of the transport system was the lack of transversal roads communicating with the border regions of the colony. During many years, this portion of the British Empire had pitiful communications with Nigeria, the territory to which it officially belonged. With French Cameroon, the exchanges were much more fluent, in particular, along the Mungo River and the Bamiléké grassfields, although they were not encouraged by the colonial administrators from both sides.

Altogether, in 1930, the transport system did not have any stretch of asphalted roads. The approximately 4,600 km of gravel roads shaped a simple network conceived to connect the coast to the interior, with two linear penetration lines from Kribi and from Victoria, one in each colonial territory. Investments were concentrated around Douala. The railway, with a total length of 447 km, was configured along two lines, one eastward ending in Yaoundé and Mbalmayo and the other towards the northeast ending in Nkongsamba. In Douala, the Wouri estuary separated the two lines. Inland, a road between Yaoundé and the West completed the triangle.

4.3.2. The transport network in Cameroon in 1955

Cameroon's economy in 1955 was largely agricultural[83], with a significant reliance on exports of raw materials to Europe. Cameroon's agricultural sector was dominated by the production of cash crops such as cocoa, coffee, palm oil, and rubber. These crops were mainly produced by small-scale farmers. Other agricultural products included bananas,

[83] Rapport Annuel du Gouvernement Français à l’Assemblée générale des Nations Unies sur l’administration du Cameroun placé sous tutelle de la France, Année 1955

plantains, yams, maize, and rice. Logging was the main activity in the forestry sector. Other forest products were rubber, oil palm, and raffia. Although significant mineral resources were identified, including bauxite, iron ore, and diamonds, the mining sector was underdeveloped. In value terms, cocoa was the largest export earner, followed by coffee and bananas. The manufacturing sector was limited and focused on the processing of agricultural products, such as cocoa and coffee. There were also some small-scale manufacturing industries producing textiles, soap, and cigarettes.

Alucam was created in 1954 as a subsidiary of the French metallurgical giant Péchiney-Ugine. When the site of Édéa in Cameroon was chosen, there was discussion about whether it would be better to choose a location near a port, even if it meant transporting the electricity. In the end, the decision was made to locate the plant near the waterfall and to transport the bulk material to the port of Douala by train. Aluminium production started in 1957 and the plant reached its full capacity in 1958 (50,000 tonnes).

The commissioning in 1955 of the bridge over the Wouri River between Douala and Bonaberi represented a milestone in the history of the transport network in Cameroon (figure 4.14). Presented at the time as one of the longest bridges in Sub-Saharan Africa[84], it unified the two rail lines, which allowed for significant economies of scale. For road transport, it was also a crucial achievement, together with the overlying of the roads to Nkongsamba and Edea. As shown on the map, the other noteworthy improvement in the network is the expansion of motorable roads, which had become densified and reaching a vast surface of the country. The extension of the network had more than doubled since 1930. Only the east and far north remained disconnected. By then, Ngaoundéré could be reached through three routes, one in the West, as imagined by the Germans, one in the centre, the first constructed by France, and one along the east via Bertoua. On the British side, connections had also improved with some roads crossing both the border with the French territory (near Tombel and Santa) and with Nigeria (near Ekok and Ofu).

Despite an evident progress over 25 years, a very small portion of the roads was asphalted (basically around Victoria, Douala and Yaoundé) and, except for some additional service tracks and the construction of the road-rail bridge over the Wouri, the railway remained unchanged. On the one hand, the significant growth of motor vehicles during those years increased maintenance needs, which are particularly important for gravel roads in tropical areas. On the other hand, the construction of culverts and permanent bridges to replace the ferries in service on the most important routes consumed an important part of the budgetary resources. For instance, 450 bridges and major culverts were identified in the stretch of road between Victoria (Limbe) and Bamenda, which “indicates the serious obstacles in the way of road construction”.[85]

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[84] Blanchet A., M. Teitgen a inauguré un des plus grands ponts d'Afrique noire, *Le Monde*, 17.05.1955

[85] United Nations Visiting Mission to Trust Territories in West Africa, 1952. Report on the Cameroons under United Kingdom Administration. Trusteeship Council, 13th Session (28 January - 25 March 1954)

Figure 4.14. Road and rail transport network in Cameroon in 1955 (Source: Author)

4.3.3. The transport network in Cameroon in 1966

In 1966, Cameroon was a newly independent country still largely dependent on the export of agricultural products. In terms of value, the most exported products in those years were coffee and cocoa, which together accounted for 45% of exports[86]. They were followed by cotton, timber, bananas, and rubber, which accounted for between 3 and 6 percent of exports. The country was beginning to invest in developing other sectors of the economy, such as manufacturing and services, to reduce its dependence on primary commodities. Indeed, agriculture, the main source of cash income for most of the population, had not made much progress because of price fluctuations on the world market (notably the fall in cocoa prices), the problems posed by independence and the loss of the French preferential markets. Mining was still underdeveloped and, except for the highly capital-intensive modern aluminium plant at Edea (ALUCAM), the creation of new industries was very limited and generally developed in the agri-food sector.

In the decade 1955-1965, the mapped road network had only increased about 500 km and the railway and the asphalted roads had increased minimally (figure 4.15). The factors for this ten-year slowdown are more temporary than structural. Firstly, as explained in this chapter, colonial powers, being confronted with increasingly intense pro-independence movements, reduced their investments in the last years of the trusteeship. Secondly, the new-born country embarked on an ambitious development plan aiming, among others, to expand the transport network. However, the recently created government structures were weak, domestic revenue low and the international financing mechanisms were still being deployed. As a result, in 1966, almost 50% of the operations in transport infrastructure planned in the First Five-Year Development Plan had to be carried over to the Second Plan. As we will see, it is from the Second Plan that results of these construction efforts start to materialise. For example, the Tiko-Douala Road, known as the Reunification Road, and the Mbanga-Kumba railway were inaugurated in 1969, which is why they do not appear on the 1966 map yet. Looking at the map in more detail, we observe that some additional roads had been paved between 1955 and 1966. For instance, part of the road from Garoua to Maroua, the road Yaoundé - Mbalmayo and the last section of the road between Douala and Bafoussam. However, the total length of asphalted roads had remained almost invariant because, at the same time, some roads, previously indicated in the maps as paved, were in 1966 considered as gravel roads. The most striking examples of this downgrading are the road Limbe-Kumba and the first section of the "Route Razel" built less than ten years earlier. It means that, due to the lack of maintenance, some roads deteriorated to such a poor condition that they were no longer considered as asphalted. Finally, we notice that, in 1966, the regions surrounding Lake Chad were by then connected by road. The only regions that remained undeserved are the dense tropical forests in the south-east.

[86] World Bank (1966), L'économie de la République Fédérale du Cameroun, Rapport no. AF-48b

Figure 4.15. Road and rail transport network in Cameroon in 1966 (Source: Author)

4.3.4. The transport network in Cameroon in 1978

In 1978, Cameroon's economy had experienced a period of growth and diversification, with some progress made in developing the manufacturing and service sectors. Agriculture remained the backbone of Cameroon's economy (36% of the GDP)[87]. The sector still employed most of the population, and the country was one of the largest producers of cocoa, coffee, cotton, palm oil, and bananas in Africa. Cameroon's manufacturing sector had grown in the years since independence, and, in 1978, it accounted for around 24% of the country's GDP. The sector was dominated by food processing, textiles, and construction materials. The government also invested in developing a cement factory and a steel mill to support the construction industry. Cameroon's mining sector remained underdeveloped, but the country had significant potential to produce bauxite, iron ore, and gold.

The period between 1966 and 1978 represents the golden era of Cameroonian transport infrastructure. Paved roads increased by 223%, going above 10% of the total network. Railways increased by 145% and the total length reached 1,105km (see table 7.1). The outstanding growth during those years can also be appreciated by comparing the 1966 map with the 1978 one (figure 4.16). The most significant achievement is, undoubtedly, the construction of the so-called Trans-Cameroon railway II between Yaoundé and Ngaoundéré. This extension, together with the Mbanga-Kumba tracks linking the French- and English-speaking regions, amounted to more than double of the previous railway length. In the following decades, the Trans-Cameroon railway became the most reliable and used land transport mode to connect the north to the south and opening the country to the sea. Almost concurrently, road infrastructure remarkably improved with the pavement of the national road No 1 connecting Ngaoundéré, Garoua, Maroua and Kousseri. Thanks to international aid, Cameroon had been able to equip itself with a backbone transport infrastructure, not only vital for the country but also serving its neighbours, Chad and Central African Republic.

As far as freight is concerned, the railway has been used up to the present day mainly for the transport of:

- Imported hydrocarbons from Douala to the three main depots located in Yaoundé, Bélabo and Ngaoundéré.
- Imported consumer products demanded in the areas accessible by rail with links from Douala to Yaoundé, North and East of Cameroon.
- Primary sector products for export: cotton fibre, logs and sawn timber.

For the internal markets of the hinterland, mainly Chad, but also CAR, rail transport consists mainly of containers for imported goods and of cotton for export.

[87] République unie du Cameroun (1976), IVe Plan quinquennal de développement économique, social et culturel (1976-1981)

Figure 4.16. Road and rail transport network in Cameroon in 1978 (Source: Author)

In addition to the rail/road route, we can observe improvements in the west of the country. The roads Douala-Limbe and Bafoussam-Bamenda had been asphalted, as well as the road Buea-Kumba and beyond, towards Mamfe. The asphalted road in the middle of the Adamaoua is a section of the Trans-African Highway Lagos-Mombasa. As we have explained previously, its position, not linking any main urban centre and far from the nearest paved road, raises many questions about the suitability of this road. Finally, we can observe a better coverage of the road network in the east and the south of the country

Despite the significant progress made, overall, transport infrastructure provision was far from the expected standards looking at the increased motorization of the country. Investment needs were still immense. Any asphalted road did not connect the north and the south of the country. Vast areas of the territory remained completely unserved by paved roads, in particular in the east and the centre.

4.3.5. The transport network in Cameroon in 1995

Cameroon started to export oil in the early 1980s. The country's first oil field was discovered in the late 1970s, and commercial production began in 1980. By 1995, oil had become an important part of the country's economy, accounting for around 9% of GDP[88]. Oil exports accounted for around 40% of Cameroon's total export revenue in 1995. However, it did not impact the transport network much as oil production is concentrated in the Rio Del Rey Basin, located in the south-western part of the country near the border with Nigeria. The basin contains several offshore oil fields, including the Kole, Ebome, and Kombe-Nsepe fields, operated by international oil companies.

Agriculture remained the largest sector of the Cameroonian economy, accounting for around 39% of GDP and employing more than half of the country's workforce. In this order, cocoa, timber, coffee, and cotton were the most important agricultural export products, whose relative importance varied depending on market conditions and other factors. Cameroon's industrial sector had grown since the 1970s, and in 1995 it accounted for around 23% of GDP. The sector was dominated by food processing, textiles, construction materials, and paper production. The services sector was also growing in Cameroon in 1995, particularly in urban areas, and accounted for 36% of the GDP.

The 1995 map (figure 4.17), a year after the devaluation of the CFA franc, reflects the situation of the transport network at the height of the economic crisis. Compared with 1978, we distinguish some additional paved roads, in particular radial links serving Yaoundé. Thanks to the construction of the roads Douala-Yaoundé and Yaoundé-Bafoussam, the triangle Yaoundé-Bafoussam-Douala could by then be travelled all over through entirely paved roads. Moreover, a new asphalt road, from Yaoundé to Ayos, was heading east. In the far north and the west of the country, we notice also some additional paved sections, but we also observe roads that had been retrograded to gravel standards.

[88] International Monetary Fund (1996), IMF Staff Country Report No. 96/125, Cameroon

Figure 4.17. Road and rail transport network in Cameroon in 1995 (Source: Author)

In the south, the most remarkable new paved roads were the ones from Edea to Kribi, from Eseka to Lolodorf and the ring in the Meyomessala subdivision, where the native village of Paul Biya is located. On the other hand, we still observe a striking absence of asphalt roads in the centre above the Sanaga and in the east. In the east, only the road linking the railway station of Belabo with Bertoua had been overlaid. It is not visible on the 1995 map, but it is important to recall that the rehabilitation and realignment works of the Douala-Yaoundé railway ended after 1978.

In sum, in the 1995 map, despite having considered that Cameroon had entered a stagnation phase, we can observe some network enlargement and improvements. This growth can be attributed to the finalisation of infrastructure projects committed before the crisis. In fact, as we have explained in section, the expenses due to these new infrastructures had contributed to worsen the economic situation. At the same time, overall progress stayed modest, and the network continued to perform poorly in large parts of the country

4.3.6. The transport network in Cameroon in 2005

In 2005, Cameroon's economy had significantly reduced its reliance on agriculture, which accounted for around 23% of GDP[89]. Important progress had been made in developing other sectors of the economy, such as manufacturing, services, and oil production. Cameroon's industrial sector had grown since 1995, and in 2005 it accounted for around 29% of GDP. The sector was dominated by food processing, textiles, construction materials, and paper production. The tertiary sector, mainly present in urban areas, accounted for 39% of the GDP. Cameroon's crude oil exports continued to dominate the country's exports, accounting for around 50% of the country's total export revenue. Cocoa accounted for around 9% of the country's total export revenue, timber 7%, aluminium 7%, cotton 7% and coffee 3%.

2005 marks the end of the economic crisis with the attainment of the completion point of the HIPC initiative. Therefore, what is expected in the visualisation of the map is a slow evolution of the transport network during the preceding period (figure 4.18). Indeed, compared with the 1995 map, we observe few additional paved sections. In addition, a relevant feature in 2005 is that two railway links ceased to exist: following the 1999 privatisation, the Otele-Mbalmayo and the Douala-Nkongsamba lines had been dismantled.

As explained in this chapter, the only road works executed during that stagnation phase were financed with international aid grants, in particular from the European Development Fund (EDF) and France. The most important projects were the road Bertoua-Garoua Boulai in the east and the south links to Gabon and Equatorial Guinea, including the bridges over the Ntem.

[89] International Monetary Fund (2005), IMF Country Report No. 05/165, Cameroon: Statistical Appendix

Figure 4.18. Road and rail transport network in Cameroon in 2005 (Source: Author)

In the map, we can appreciate that the choice of Bertoua-Garoua Boulai, in view of completing Ayos-Bertoua and further sections in the future, has an evident benefit as it serves not only the east and the north of Cameroon but is also crucial for the neighbour countries, both Chad and Central African Republic. On the other hand, this option meant that, to secure the benefits of the precedent works, investments would have to continue along the same corridor, and thus complete it. Consequently, in the following years, the western corridor (via Foumban) and the central corridor (via Yoko), shorter ways to reach the north, were neglected and remained as gravel roads in poor condition.

4.3.7. The transport network in Cameroon in 2015

Despite robust growth in the preceding years, driven by rising oil production and the performance of sectors benefiting from the public investment boom (building materials, construction, and energy), in 2014, Cameroon suffered two major shocks[90]. First, the fall in international oil prices reduced government revenues and exports. Second, the wave of terrorist attacks in the Lake Chad region had disrupted economic activity in Cameroon's far north, requiring large-scale military operations in response. The primary sector accounted for 20.9% of GDP, the secondary sector excluding hydrocarbons 20% and the tertiary sector 37.4%. The government contributed 17.8% of GDP.

In the decade between 2005 and 2015, the length of the paved network continued to grow at a similar rate as in the previous period (see section 6.2). The most remarkable achievements were the completion of the road connection south-north along the east (via Bertoua) and the road from Ngaoundéré towards the border with Chad (an important link at regional level) (figure 4.19).

There were also significant improvements in the Anglophone regions with the pavement of the road between Bamenda and the Nigerian border and sections of the Kumba-Mamfe road. From a qualitative point of view, the complete overlying of the Yaoundé-Bertoua-Ngaoundéré road represented a fundamental change in the functioning of the network. This was the first time in the history of Cameroon that the paved network was entirely connected from Douala to Kousseri..

The available data from the Ministry of Public Works show that, in the period, there were considerable expenses to rehabilitate old road sections, in particular along the Ngaoundéré-N'djamena corridor, which was mainly built in the 1970s. Obviously, these rehabilitation projects are not visible by comparing the 2005 and 2015 maps because the concerned sections have always been considered as paved, even if in poor conditions. As a result, the increasingly higher budget allocated to the road sector did not necessarily mean a proportional expansion of the paved network, as maintenance needs were also growing.

[90] International Monetary Fund (2015), IMF Country Report No. 15/331, Cameroon.

Figure 4.19. Road and rail transport network in Cameroon in 2015 (Source: Author)

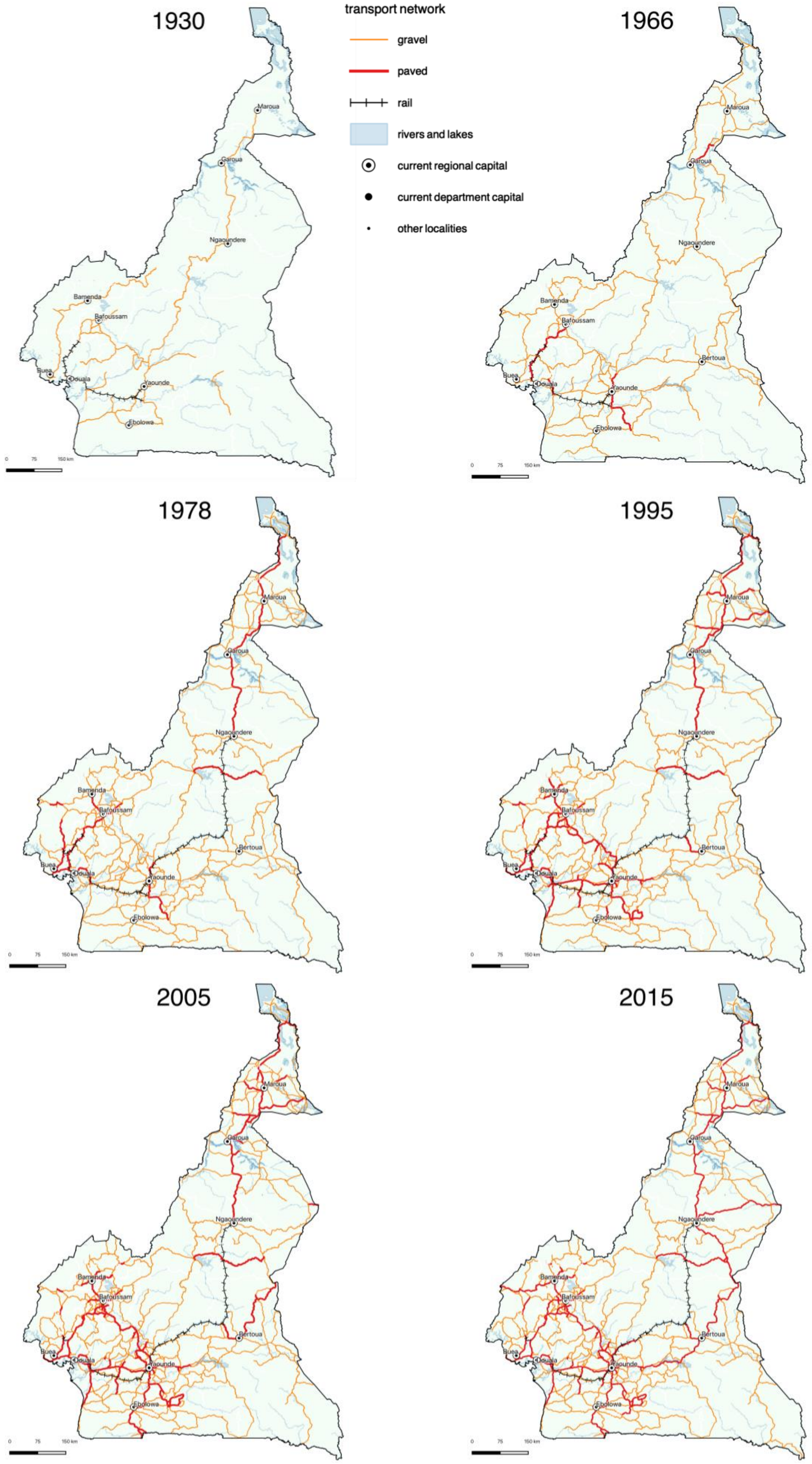


Figure 4.20. Transport network in Cameroon in studied years (Source: Author)

4.4. Conclusions of the geohistorical review: network development periods according to spatiotemporal paradigms

The geohistorical review carried out to analyse the evolution of transport networks in Cameroon shows that, for each political regime and for each development paradigm the role of transport was different. We therefore see that it is possible to divide and characterise the evolution of the network into distinct periods. This is what we are going to do in this conclusion chapter.

For a better appreciation of the dynamics of the evolution of the networks described in the previous sections, figure 4.20 above shows a joint visualisation of the maps. A general observation that can be drawn from putting the maps together is the apparent correspondence with the Taaffe, Morrill and Gould model (figure 2.2). In the first map from 1930, we notice a similitude with diagrams B and C of the model, which correspond to the construction of penetration lines, port concentration and development of feeder roads. The 1955 map indicates the process of interconnection, which is consistent with what the model proposes in diagram D. 1978 would mark the complete interconnection or full connectedness (as described in diagram E). It is the moment when all the department capitals (*chef-lieu de département*) are connected. Finally, the evolution of the asphalt network from 1995 to 2015, illustrates what diagram F suggests: an "emergence of high priority 'main streets'". Indeed, looking at the maps we can clearly identify the formation of a unique principal corridor, linking the south and the north of the country through the east, via Bertoua and Garoua-Boulai, and a triangular road connecting Douala-Yaoundé and Bafoussam. The rest of the paved roads in the country feed these two main systems.

Continuing and deepening this approach, we can identify six different periods of evolution of the transport network in Cameroon and establish some correspondence to the phases and patterns proposed by Taaffe, Morrill and Gould (1963), in figure 2.2, and Debrie (2010), in figures 2.4 and 2.5:

<u>COLONIAL PERIOD (1882-1960)</u>

- C1. 1882-1916 (German Colonial Empire, before World War I) – Exploration of routes
- C2. 1917-1945 (French & British Mandate, between World Wars) – Selection of penetration routes
- C3. 1946-1960 (French & British Trusteeship, after World War II) – "Fertile crescent", the useful Cameroon

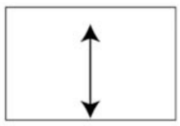
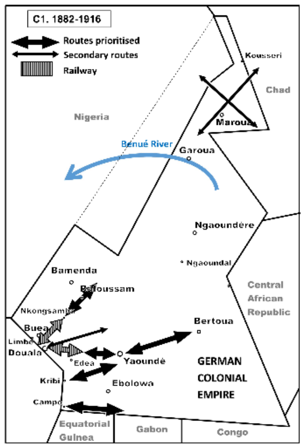
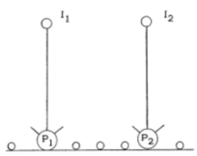
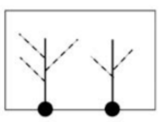
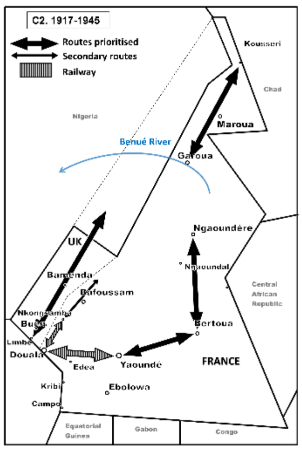
<u>NATIONAL PERIOD (1961-2005)</u>

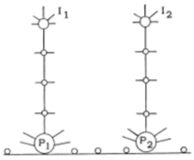
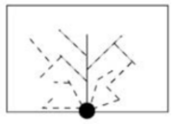
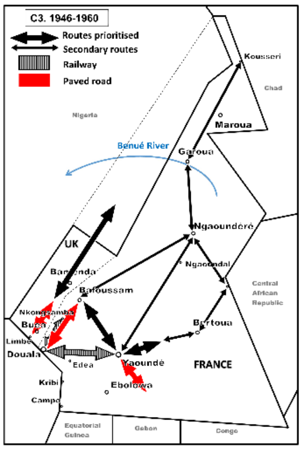
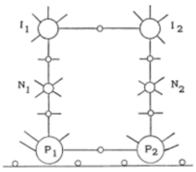
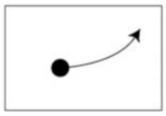
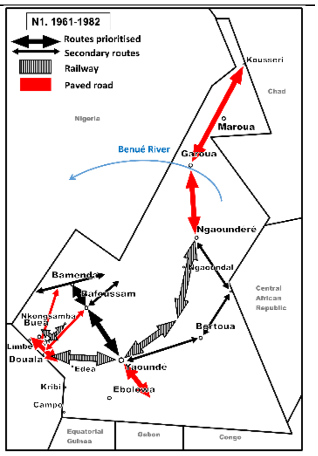
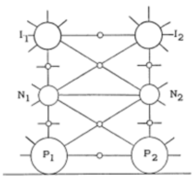
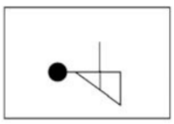
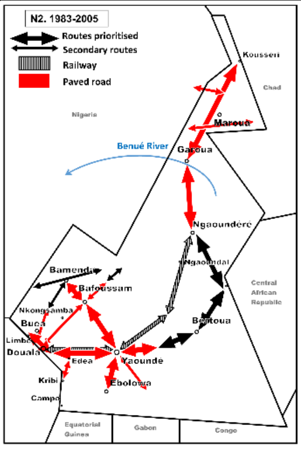
- N1. 1961-1982 (National – President Ahidjo, national autonomy) – Unification corridors
- N2. 1983-2005 (National – President Biya, donor dependency) – Internal economic interconnection

<u>REGIONAL PERIOD (2006-2015)</u>

- R1. 2005-2015 (National – President Biya, emergence of non-Western donors) – Regional corridors and network of agglomerations

Therefore, based on the geohistorical review, table 4.3 depicts these six historical periods in Cameroon and associates them with their existing political regime, the international development paradigm prevailing at the time and the main function of the transport network. This allows us to establish in each of the six periods a general outline of the development of the transport network, which we have represented in the last column.

Period	Years	Regime	Development paradigm	Function of transport	Taaffe's phases / Debrie's patterns	Transport network outline
C1	1884 1916	German Colonial Empire	Exploratory extroverted economy	Extraction, territorial control	 A. Scattered ports  Project of exploitation	 **Exploration of routes**
C2	1917 1945	French & British Mandate	Selective extroverted economy	Extraction, territorial control	 B. Penetration lines and port concentration  Penetration routes	 **Selection of penetration routes**

C3	1946 1960	French & British Trustee-ship	Assimilation (FR) Autonomy (UK)	Export-import, modernisa-tion	 C. Development of feeders  Network of paths	 **"Fertile crescent", the "useful Cameroon"**
N1	1961 1982	National President Ahidjo	Developmen-talism, national autonomy	National construction	 D. Beginnings of interconnection  Territorial corridors	 **Unification corridors**
N2	1983 2005	National President Biya	Structural adjustment, donor dependency	Internal operations	 E. Complete interconnection  Internal economic corridors	 **Internal economic interconnection**

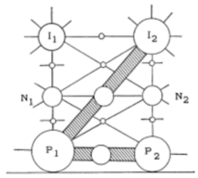
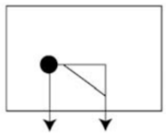
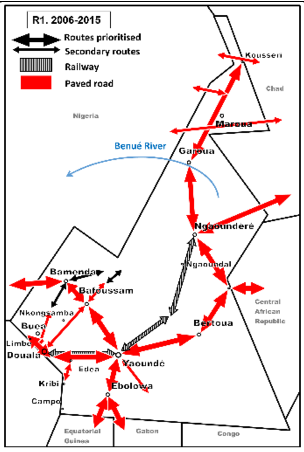
R1	2006 2015	Regional President Biya	Regional integration, emergence of non-Western donors	Trade facilitation	 F. Emergence of high priority "main streets"  External connection corridors	 **Regional corridors, and network of agglomerations**

Table 4.3. Periods, regimes and paradigms of development and corresponding spatiotemporal outlines of the transport network in Cameroon (Source: Author)

These successive periods and corresponding outlines will be the basis for the analysis in the next chapters and will be a useful tool to explain the discrepancy over time between the maximum, planned, decided and executed network. It should be noted that politically, the change between the N1 and N2 period occurred in 1982-1983 when the presidency of the Republic passed from Ahmadou Ahidjo to Paul Biya. However, from an economic point of view, the turning point came in 1985-1986 when Cameroon began to show clear signs of bankruptcy. In this thesis, we will indistinctly use one date (1982-1983) or the other (1985-1986) to indicate the change of period between N1 and N2.

Figure 4.21 contains the six schematic maps illustrating the evolution of Cameroon's transport network outline. By putting them together, we can compare them and see what the main characteristics of each period are. During the colonial era, we can distinguish three development paradigms. In periods C1 and C2, in the German Colonial Empire and during the French and British inter-war mandates, the principle of economic extroversion based on the self-sufficiency of the colonies predominated. Both colonial powers based infrastructure development on private sector capital, and the purpose of transport was essentially to extract raw materials and agricultural products as well as to control the territory militarily. However, the region was vast, and the orography and natural conditions made penetration into the territory particularly difficult. In fact, the northern part was so distant and isolated that trade was not done through Cameroonian territory but by river, via the Benué, and northwards across the Sahara.

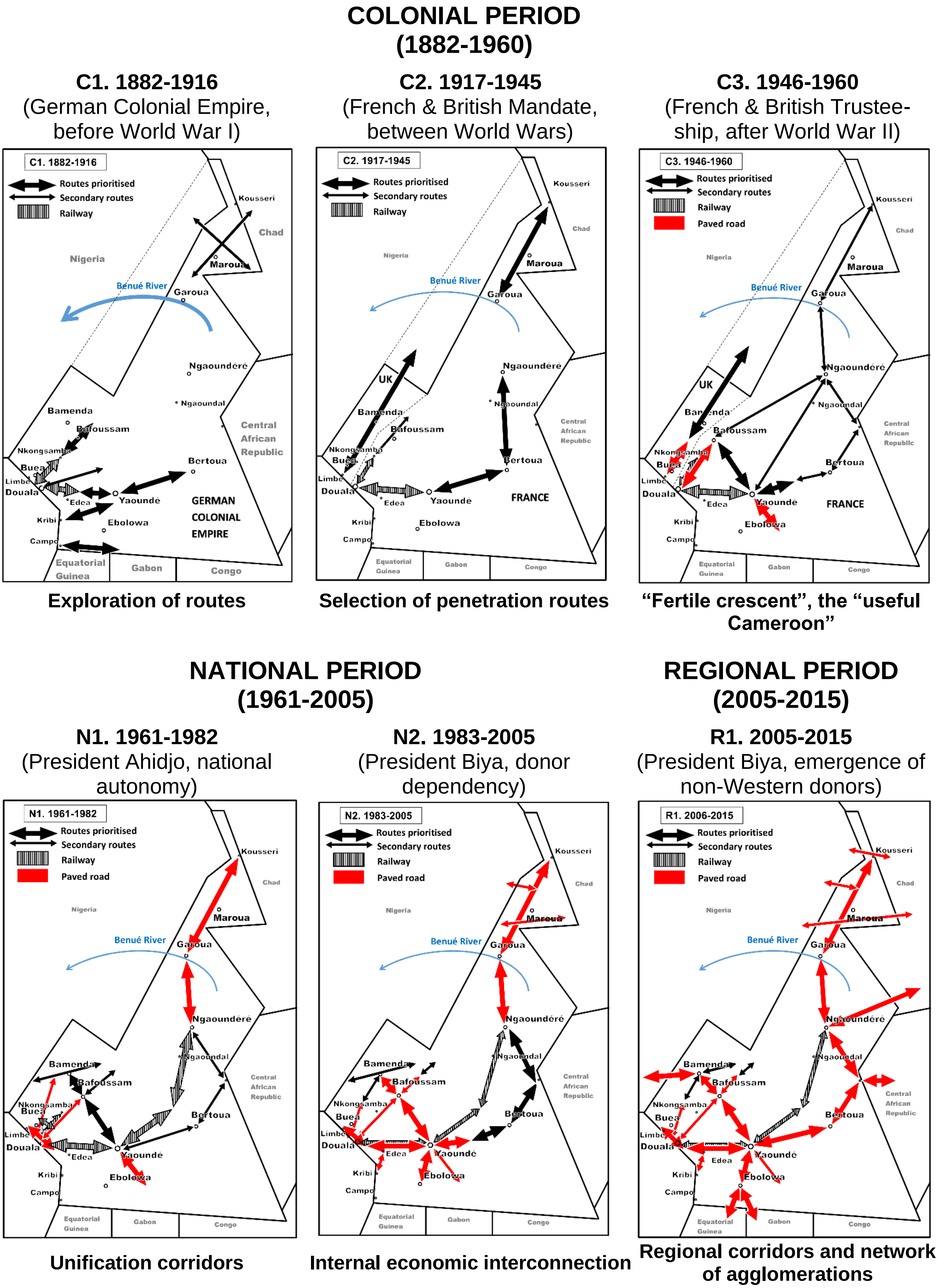


Figure 4.21. Evolution of the spatiotemporal transport network in Cameroon (Source: Author)

In period C1, of German colonisation, the network was shaped by the exploitation of the territory from the various identified ports (today Limbe, Tiko, Douala, Kribi and Campo), prioritising direct entry routes to the interior from the coast, while communications from the north were based on the Benué River. The early years of period C1 correspond to phase A of the Taaffe, Morrill and Gould model, in which scattered ports appeared, giving access to a limited hinterland. It ends in phase B, characterised by the concentration of ports and the beginning of the development of penetration routes. Debrie describes it graphically in a simple way: the delimitation of the colonial bloc in which the colonising power has a project of exploitation but in which the accesses to the interior are being tested guided by a strategy of minimum investment.

In period C2, on the German basis, French colonisation focused on the central corridor given the scarcity of resources exacerbated by the Great Depression starting in 1929. Hence its selection and concentration of investments in one corridor starting in the port of Douala. In the same spirit, British colonisation focused on a single corridor to Bamenda and the Northern Cameroons (now Nigeria) starting in the port of Victoria (Limbe). In this period, at the beginning of the British and French mandate, the network pattern corresponds to phase B of the Taaffe, Morrill and Gould model called “penetration lines and port concentration”. Debrie describes these selected penetration routes as an attempt by the colonial powers to carry out an "economic structuring" of the territory.

Period C3 is defined by the generalisation of the automobile in Africa and thus of the first paved roads. These investments were costly and concentrated on the most profitable areas, the closest to the coast. In this period, the bridge over the Wouri River between Douala and Bonaberi was built. It is a key infrastructure for connecting the west with the east and south of the network, both by rail and road. The policies of French assimilation and British autonomy, although apparently different, had one thing in common from the point of view of infrastructure investment: the economic viability of the territories. The aim was to improve the living conditions of the population and, at the same time, benefit the mother country. To this end, the priority was to increase the export of cash crops and the import of industrial products manufactured in the *métropole*. For these reasons, investments were concentrated in what the French called the “fertile crescent” or the “useful Cameroon”, which is basically the semi-circle with a radius of 300-350 km from Douala and, for the British, the axis between Victoria and Bamenda.

Debrie defines the network in this third period as a “network of paths”, a concept equivalent to phase C of the Taaffe, Morrill and Gould model called “development of feeders”. This is precisely what happened in Cameroon: improved paved access to the ports of Douala and Victoria, to the head of the railway line and to the capital, Yaoundé. However, this modernisation of certain sections did not improve the connectedness of the transport network as a whole.

Period N1, which begins with independence, is well described by Debrie for the case of continental West African countries, in what he calls "territorial corridors". A very similar development to "the national road or the eastward link" as depicted by Debrie can be observed in Cameroon. The authorities endeavoured to unify the country from the centre of the territory and its capital, Yaoundé, by developing transport infrastructures to the west and to the east/north. Connections to the west were a necessity for reunification of the territory, which was then under a single regime, because transport between the two territories was unreliable during the separation under the French and British rule. The link towards the east and the north followed the same alignment that the French had prioritised in period C2. This corridor was completed thanks to the railway from Douala to Ngaoundéré and the asphalting of the road running south to north from Ngaoundéré to Ndjamena. It was not only an economic infrastructure, but also a politically symbolic one, because, for the first time, the north and the south of the country were connected by modern transport infrastructure. Goods were no longer so dependent on the Benue River for transportation.

In this sense, Cameroon's transport network in period N1 corresponds to what Taaffe, Morrill and Gould call the phase of the "beginnings of interconnection" (phase D). In this period, the network was connected on a territory-wide scale, but connectivity was still precarious, in an arborescent form.

In period N2, during the economic crisis of the 1980s and 1990s, Cameroon was strongly affected by structural adjustment programmes, which had a significant impact on infrastructure management policies. Railways went into relative decline leading to privatisation and closure of the least profitable lines. With the few resources available, the government concentrated on developing and paving internal road connections. It is during this period that the Douala-Yaoundé-Bafoussam/Bamenda road triangle was completed, paved and improved. This is what Debrie calls "internal economic corridors". One decision that had a major impact in the following decades was to develop an alternative road to the railway linking Yaoundé and Ngaoundéré. For this purpose, the eastern route was chosen, as it offers, from Yaoundé, both accessibility to the north of Cameroon and to the neighbouring Central African Republic.

Regarding the Taaffe, Morrill and Gould model, this period corresponds to phase E, "complete interconnection". However, while it is true that in those years it was possible to reach most of the country's cities by road, the quality of the service was unequal. Due to the lack of resources, the paved network covered a reduced part of the territory. Therefore, if interconnection is considered as the existence of a network that allows the country to be connected by roads in good condition, then Cameroon was far from having a complete network.

In period R1, the development of the transport network in Cameroon is a good example that illustrates both models, the one proposed by Debrie, in what he calls "external connection corridors", and the stage F of Taaffe, Morrill and Gould, which they characterised as the “emergence of high priority main streets”. The asphalting of the road linking Yaoundé and Ngaoundéré, via Bertoua and Garoua-Boulai, was completed. From that moment it was possible to travel on paved roads from Douala to Ndjamena without disruption. Ndjamena could even be reached by paved road from Bamenda and Buea via Yaoundé. This is the corridor that we would call “high priority main street”. At the same time, we observe that, in this period, from the main transport corridor, asphalted roads were built to link up with neighbouring countries. For example, the routes from Bamenda to Nigeria, from Mbalmayo to Gabon and Equatorial Guinea, and from Ngaoundéré to Chad were completed. Also, in the interior of the Central African Republic, sections of road were asphalted to link Garoua-Boulai with the capital, Bangui. Thus, Cameroon's main internal corridor became a regional corridor to facilitate trade and regional economic integration.

It can therefore be concluded that the six periods we have identified to characterise the development of the transport network in Cameroon correspond to the six stages proposed by Taaffe, Morrill & Gould in 1963 and to the six outlines identified by Debrie in 2010 for landlocked West African countries. This segmentation into historical periods allows us to establish at what points in history and for what reasons the executed network evolves towards the maximum network and whether there are divergences. But we do not know yet to what extent this happens. We need to quantify these convergences or divergences. This is what we will do in the next chapters.

5. Structural analysis of the transport network

5.1. Shortest-paths network analysis

Table 5.1 presents the results of the shortest path analysis calculated for direct distances and transport distances. Under "direct distances", we assign the same speed to all the road and rail links. In the "transport distances" calculation, each section is travelled at a speed close to the real conditions, as explained in section 3.2.1.

	1930	1955	1966	1978	1995	2005	2015
localities (n)	107	208	213	286	288	296	299
shortest paths	3,744	20,712	22,578	40,755	41,328	43,660	44,551
total network length	4,591	10,331	10,731	17,684	18,659	21,291	22,112
diameter (direct distance)	1,531.65	1,638.98	1,818.54	1,822.90	1,760.30	1,760.30	1,809.04
diameter (transport distance)	1,548.03	1,778.42	1,882.50	1,877.07	1,791.23	1,968.27	2,226.18
total direct distances	1,853,143	13,384,353	14,843,800	25,990,221	26,365,484	28,045,962	28,688,639
total transport distances	1,857,335	13,782,918	15,616,894	26,916,385	27,787,177	29,525,519	32,816,026
average shortest path	496.08	665.46	691.69	660.44	672.36	676.26	736.59
detour index (network)	1.00	0.97	0.95	0.97	0.95	0.95	0.87

Table 5.1. Selected results for shortest-path analysis in the observed years (Source: Author)

The diameter is the length of the longest shortest path between two localities in the network (i.e., the most distant localities). We observe that, while in direct distances it stabilises at around 1,800 km, in transport distances it goes beyond 2,200 km in 2015. This gap is a consequence of the heterogeneity of the network.

The detour index, as defined in section 3.2.1, has been continuously decreasing since colonial times (figure 5.1), notably between 2005 and 2015 where it has experienced a sharp drop. The reason is that the asphalting of the network has been done following a reduced number of major roads, in particular the one going from Yaoundé to Ngaoundéré through Bertoua and Garoua-Boulai. At the same time, old, asphalted sections have not been maintained adequately and the level of service has decreased. The only exception to the general decline of the index is the period between 1966 and 1978 where a slight positive trend regarding the uniformization of the network can be observed.

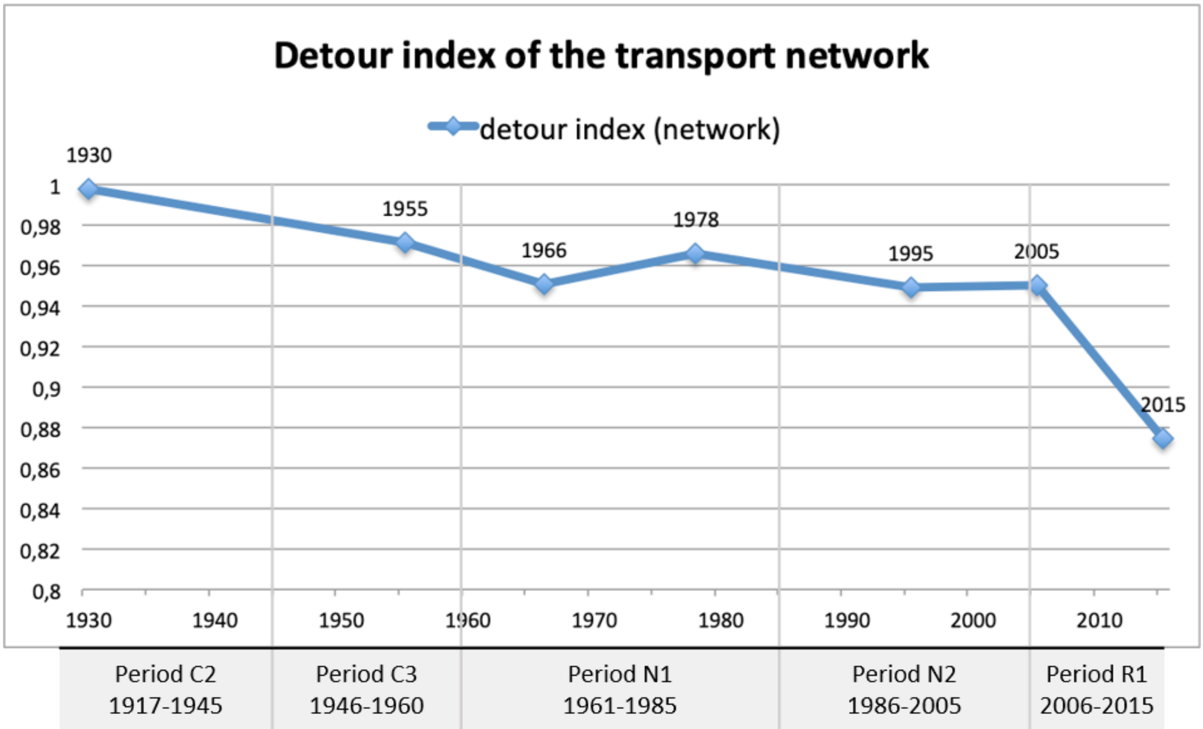


Figure 5.1. Evolution of the detour index over time (Source: Author)

As a result, since the time reduction generated by paved roads have implied longer distances, the network has become less efficient and generated access inequalities. The most striking example has been the access to the north of the country from the western regional capitals of Bamenda and Bafoussam. Table 5.2 indicates the transport distances of the network in 2015 according to real conditions. Table 5.3 shows the direct distances as if all the links could be travelled at 50 km/h. Calculating the difference between transport distances and direct distances in table 5.4, we observe that in some cases the shortest paths between two capitals imply travelling 200 km more in transport distances than in direct distances.

	Ngaoundéré	Yaoundé	Bertoua	Maroua	Douala	Garoua	Bamenda	Bafoussam	Ebolowa	Buea
Ngaoundéré	0	834	494	477	1072	273	688	610	978	1138
Yaoundé	834	0	340	1312	248	1107	371	292	156	314
Bertoua	494	340	0	971	578	767	712	632	484	644
Maroua	477	1312	971	0	1549	204	1165	1087	1456	1615
Douala	1072	248	578	1549	0	1345	320	263	394	72

Garoua	273	1107	767	204	1345	0	961	883	1251	1411
Bamenda	688	371	712	1165	320	961	0	79	527	335
Bafoussam	610	292	632	1087	263	883	79	0	448	278
Ebolowa	978	156	484	1456	394	1251	527	448	0	459
Buea	1138	314	644	1615	72	1411	335	278	459	0

Table 5.2. Transport distances between regional capitals in 2015 (Source: Author)

	Ngaoundéré	Yaoundé	Bertoua	Maroua	Douala	Garoua	Bamenda	Bafoussam	Ebolowa	Buea
Ngaoundéré	0	612	387	471	851	273	682	606	763	874
Yaoundé	612	0	336	1083	241	885	371	292	151	310
Bertoua	387	336	0	858	575	660	623	544	453	644
Maroua	471	1083	858	0	1322	198	1152	1076	1234	1344
Douala	851	241	575	1322	0	1124	301	253	279	72
Garoua	273	885	660	198	1124	0	954	878	1036	1146
Bamenda	682	371	623	1152	301	954	0	79	506	316
Bafoussam	606	292	544	1076	253	878	79	0	427	268
Ebolowa	763	151	453	1234	279	1036	506	427	0	349
Buea	874	310	644	1344	72	1146	316	268	349	0

Table 5.3. Direct distances between regional capitals as if in 2015 all the links could be travelled at 50 km/h (Source: Author)

	Ngaoundéré	Yaoundé	Bertoua	Maroua	Douala	Garoua	Bamenda	Bafoussam	Ebolowa	Buea
Ngaoundéré	0	-222	-107	-6	-221	0	-6	-4	-215	-264
Yaoundé	-222	0	-5	-229	-7	-222	0	0	-5	-4
Bertoua	-107	-5	0	-114	-3	-107	-89	-89	-31	0
Maroua	-6	-229	-114	0	-227	-6	-13	-11	-222	-271
Douala	-221	-7	-3	-227	0	-221	-19	-10	-114	0

Garoua	0	-222	-107	-6	-221	0	-7	-5	-215	-265
Bamenda	-6	0	-89	-13	-19	-7	0	0	-21	-19
Bafoussam	-4	0	-89	-11	-10	-5	0	0	-21	-10
Ebolowa	-215	-5	-31	-222	-114	-215	-21	-21	0	-111
Buea	-264	-4	0	-271	0	-265	-19	-10	-111	0

Table 5.4. Regional capitals shortest path difference between direct distances and transport distances in 2015 (Source: Author)

The biggest difference is when travelling from Buea to Maroua, where the shortest path implies 271 km more. This detour can be observed in the map of figure 5.2. If we take into consideration the travel distances indicated in the 2014 official map of the Ministry of Public Works (table 5.5), these differences are even bigger. When calculating the distances, the Ministry assumes that drivers go from Bamenda and Bafoussam to Nagoundérée through Yaoundé and Bertoua, which is the paved road.[91]

	Ngaoundéré	Yaoundé	Bertoua	Maroua	Douala	Garoua	Bamenda	Bafoussam	Ebolowa	Buea
Ngaoundéré	0	856	511	481	1096	276	1222	1144	996	1165
Yaoundé	856	0	345	1337	240	1132	371	293	157	309
Bertoua	511	345	0	992	585	787	711	633	485	654
Maroua	481	1337	992	0	1577	205	1703	1625	1477	1646
Douala	1096	240	585	1577	0	1372	330	252	390	69
Garoua	276	1132	787	205	1372	0	1498	1420	1272	1141
Bamenda	1222	371	711	1703	330	1498	0	78	528	360
Bafoussam	1144	293	633	1625	252	1420	78	0	450	282
Ebolowa	996	157	485	1477	390	1272	528	450	0	459
Buea	1165	309	654	1646	69	1141	360	282	459	0

Table 5.5. Official distances between capitals according to the Ministry of Public Works (MINTP, 2014)[92]

[91] We could not find surveys supporting that choice. Such a survey should also discriminate by type of vehicle, as this indirect route may be beneficial for some purposes but not for others.

[92] MINTP (2014), Carte générale des routes du Cameroun, ministère des Travaux publics, Édition 2014

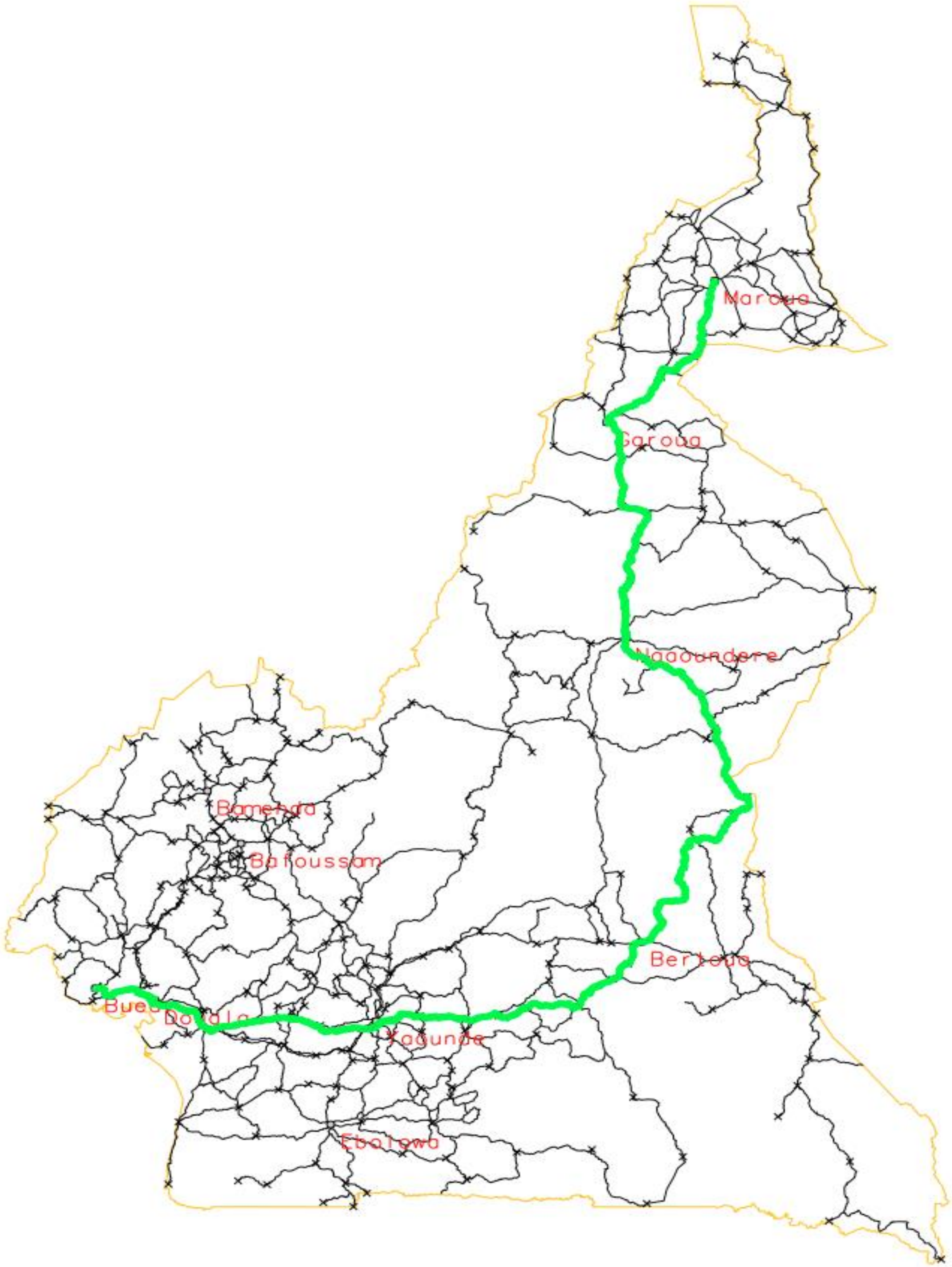


Figure 5.2. Transport distances shortest path between Buea and Maroua calculated for 2015 (Source: Author)

As table 5.6 shows, in some cases the trips can be more than 530 km longer than if travelling through the direct west route closer to the Nigerian border that is not paved.

	Ngaoundéré	Yaoundé	Bertoua	Maroua	Douala	Garoua	Bamenda	Bafoussam	Ebolowa	Buea
Ngaoundéré	0	-22	-17	-4	-24	-3	-534	-534	-18	-27
Yaoundé	-22	0	-5	-25	8	-25	0	-1	-1	5
Bertoua	-17	-5	0	-21	-7	-20	1	-1	-1	-10
Maroua	-4	-25	-21	0	-28	-1	-538	-538	-21	-31
Douala	-24	8	-7	-28	0	-27	-10	11	4	3
Garoua	-3	-25	-20	-1	-27	0	-537	-537	-21	270
Bamenda	-534	0	1	-538	-10	-537	0	1	-1	-25
Bafoussam	-534	-1	-1	-538	11	-537	1	0	-2	-4
Ebolowa	-18	-1	-1	-21	4	-21	-1	-2	0	0
Buea	-27	5	-10	-31	3	270	-25	-4	0	0

Table 5.6. Difference between regional capitals official distances according to the Ministry of Public Works and transport distances provided by shortest paths (Source: Author)

The shortest paths analysis shows how the land transport network has evolved in an ill-shaped manner. The improvement of the infrastructure has allowed connecting the south and the north of the country both by rail and by a paved road. However, as we have seen in previous sections, of the three road options historically envisaged, via Foumban, via Yoko and via Garoua Boulai, only the latter was developed in 2015. As a result, the network is skewed towards the east, obliging most of the trips to do a significant deviation.

5.2. Efficiency and connectivity of the network

5.2.1. Connectivity

We now study the graphs representing the network in Cameroon in the selected years, as presented in section 3.2. We first calculate the indices alpha, gamma and GTP. The indices compiled in table 5.7 are highlighted in green when the value reaches the threshold for a grid configuration.

	1930	1955	1966	1978	1995	2005	2015
alpha index	0.015	0.067	0.086	0.229	0.243	0.272	0.309
gamma index	0.127	0.276	0.295	0.473	0.484	0.512	0.540
GTP index	0.034	0.151	0.192	0.512	0.543	0.607	0.689

Table 5.7. Evolution of the alpha, gamma and GTP indices of the transport network in Cameroon

We conclude that, according to criteria set out by Usui and Anami, the tree form of the transport network has prevailed for many decades after independence. It is only from 2005 that the grid pattern is well laid out, as at least two out of the three indices are higher than their respective threshold for grid pattern (in fact, the three indices comply with that requisite: α > 0.25, γ > 0.5 and GTP > 0.5). However, we observe that from 1978 and, in particular, in 1995, both alpha and gamma are very close to the minimum value to consider the network as having a grid shape. We also notice that the graph is still far from becoming a delta pattern, which would correspond to the higher levels of connectivity.

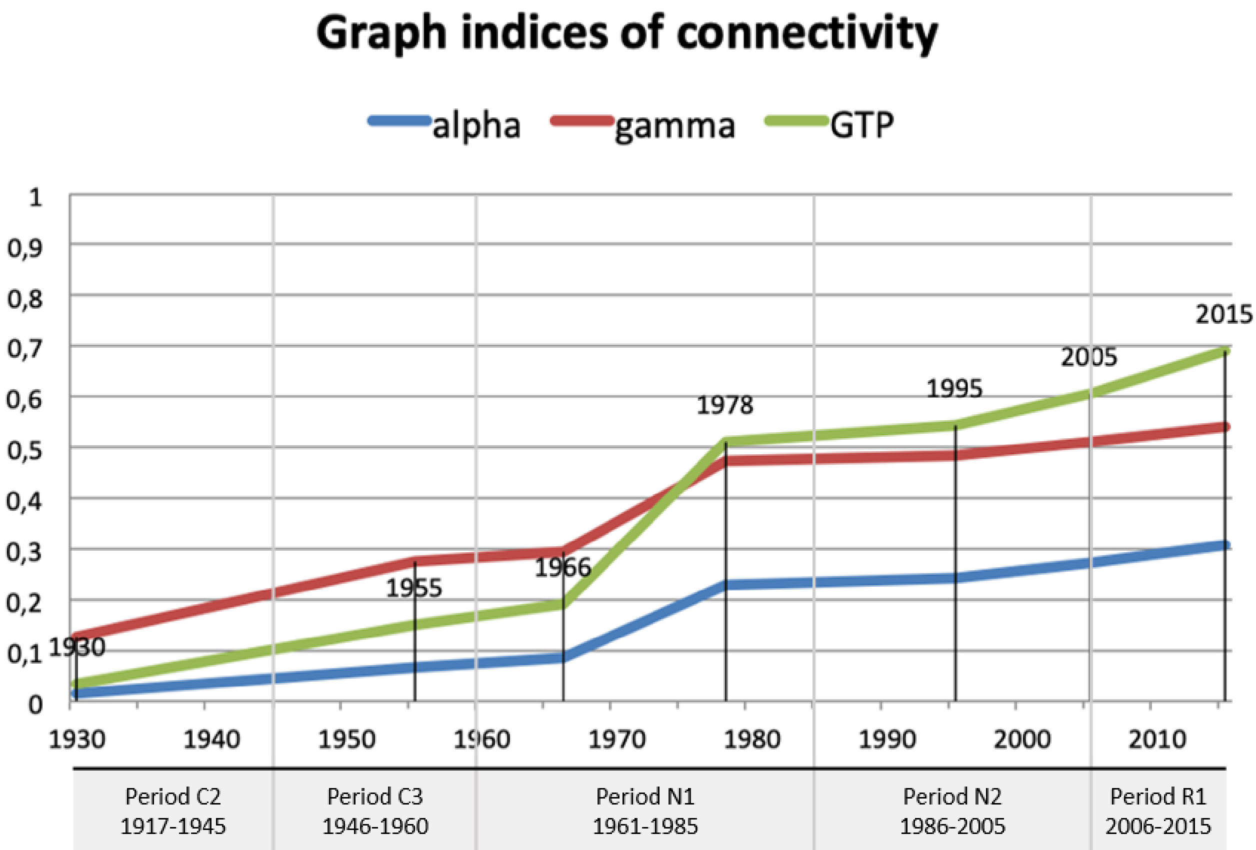


Figure 5.3. Evolution of the alpha, gamma and GTP indices of the transport network in Cameroon (Source: Author)

The values of graph indices describing connectivity are represented in figure 5.3. They show a continuous increase of the indices, with a more pronounced upward trend between 1966 and 1978. This finding coincides with the description of the evolution of the network done in the previous section, and notably with the completion of the railway between Yaoundé and Ngaoundéré. In conclusion, returning to the concepts of connectedness (*connexité*) and connectivity described by Dupuy, in Cameroon, high levels of connectedness were not reached until the late 1970's. From then, connectivity has been progressively improving, although there are still multiple options to develop alternative links in the network.

5.2.2. Degree distribution

As we have seen in the literature, the degree centrality is not a very useful measure in the case of spatial networks. However, in the case of the formation of new transport networks like in Cameroon, it is interesting to see how the distribution went from being very peaked in the 1950s and 1960s to a more rounded shape in recent years (figure 5.4). The average degree has increased from two to three, indicating a better connection of the nodes in the network. In 2015, only two cities had the highest degree of 8 connecting links, which were Yaoundé and Maroua.

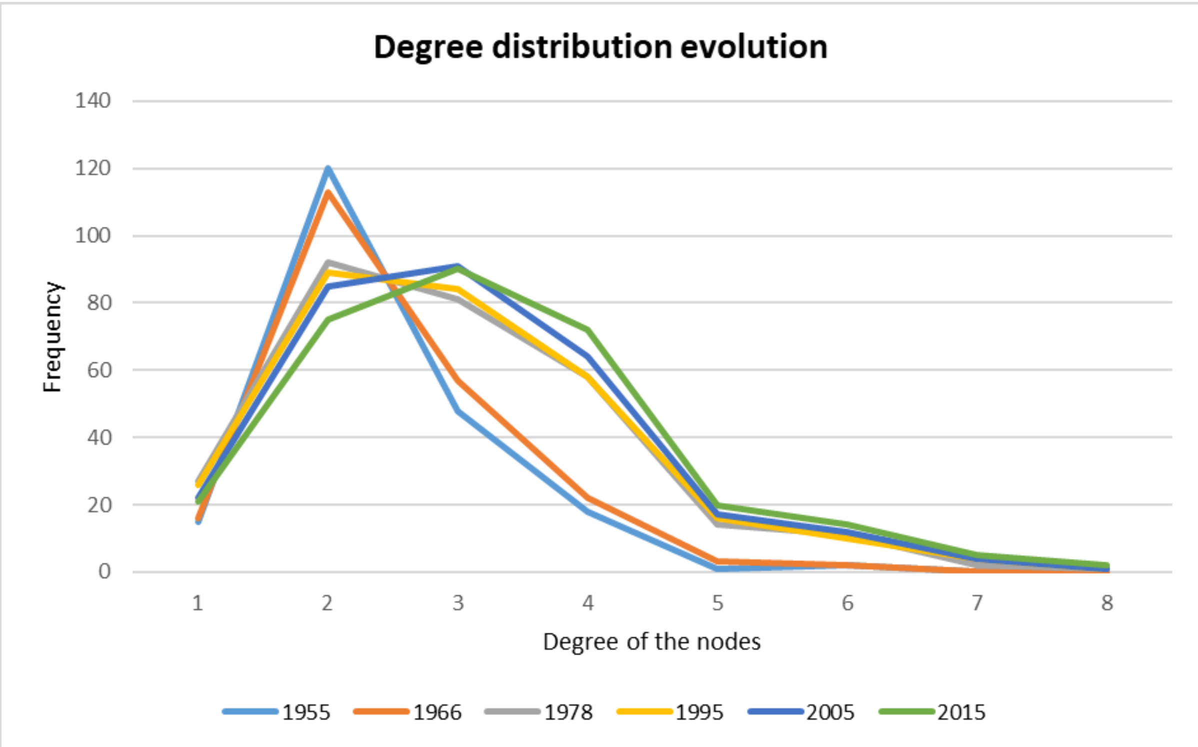


Figure 5.4. Evolution of the degree distribution of the nodes (Source: Author)

5.2.3. Closeness centrality

Following the definition of section 3.2.3, we calculate the closeness centrality of the urban centres in the network's planar graph. The ten localities with the lowest closeness value for every calculated year are shown in table 5.8. As it can be observed in the graph in figure 5.5, they are all near Yaoundé, within a radius of about 150 km, and most of them remain among the top ten in the different rankings.

1955	1966	1978	1995	2005	2015
Ntui	Yaoundé	Obala	Batchenga	Batchenga	Yaoundé
Sa'a	Mbalmayo	Batchenga	Ntui	Obala	Awae
Boura	Obala	Yaoundé	Obala	Ntui	Mbankomo
Obala	Sa'a	Mbandjock	Yaoundé	Mbandjock	Obala
Batchenga	Ngoumou	Nkoteng	Mbandjock	Yaoundé	Mekong
Bafia	Otele	Ebongo	Boura	Nkoteng	Soa
Yaoundé	Matomb	Sa'a	Nkoteng	Ebongo	Ayos
Ezezang	Makak	Nanga Eboko	Ezezang	Mbankomo	Batchenga
Ombessa	Boumnyebel	Matomb	Ebongo	Ezezang	Atok
Ndikinimeki	Ezezang	Okola	Bafia	Nanga Eboko	Ezezang

Table 5.8 Localities with the lowest closeness value in the graph (Source: Author)

Table 5.9 and figure 5.6 represent the evolution of the closeness for the regional capitals. Values are given in hours. For instance, in 2005, the average time of the shortest paths from Bafoussam to all the other connected localities in the network was 13.86 hours. This value is obtained by dividing the time needed to travel through shortest paths from Bafoussam to all the other localities in the graph for a given year divided by N-1, where N is the number of connected localities (296 in 2005).

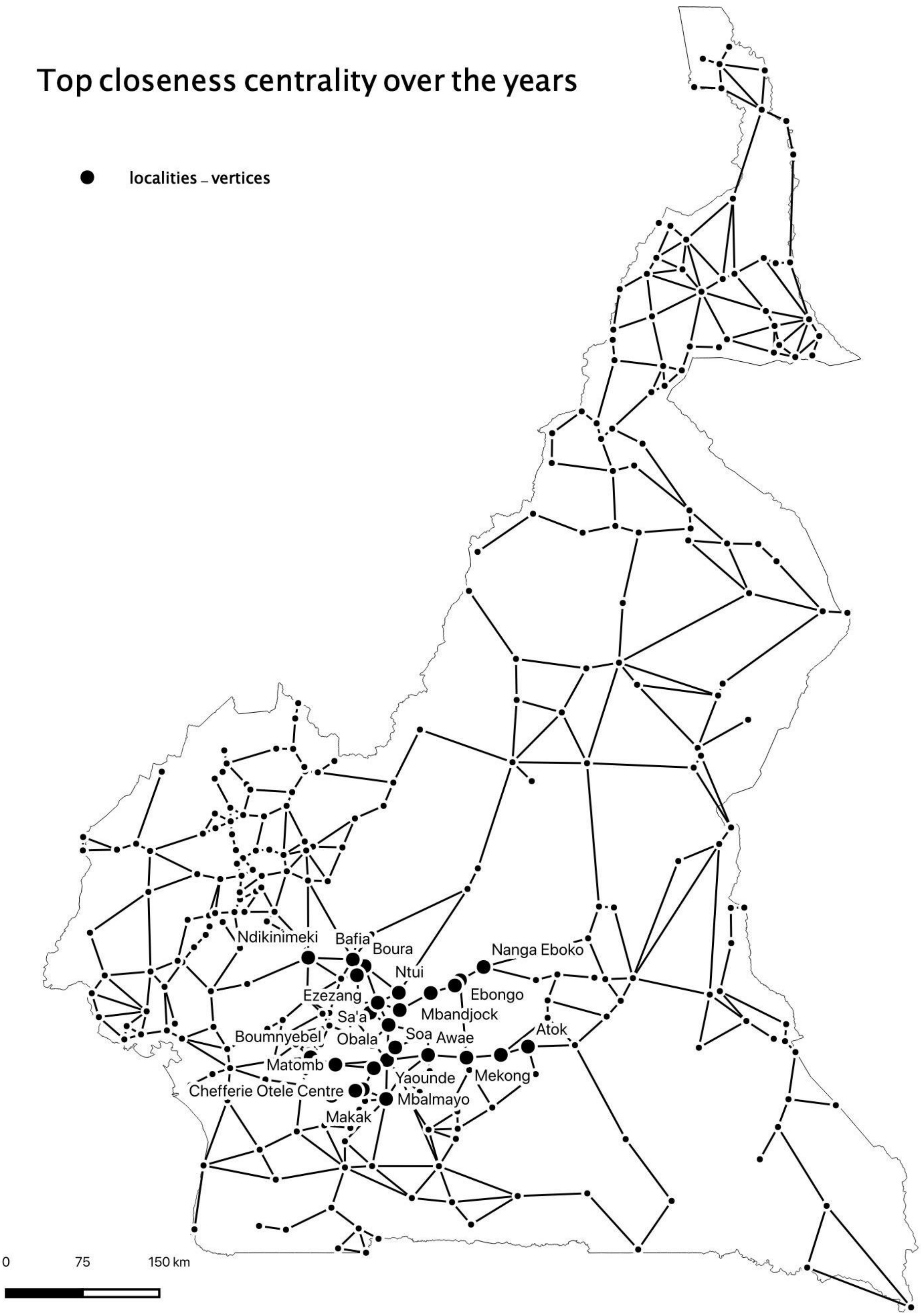


Figure 5.5. Planar graph for 2015 where the most central localities (lowest closeness values) calculated since 1955 have been mapped (Source: Author)

	1955	1966	1978	1995	2005	2015
Ngaoundéré	17.43	20.45	12.86	13.09	15.10	13.60
Yaoundé	12.17	14.76	10.21	9.43	11.89	10.31
Bertoua	14.19	18.16	12.16	10.95	13.31	11.14
Maroua	25.83	28.37	17.81	17.30	23.63	20.92
Douala	13.67	15.30	11.57	10.80	13.28	11.70
Garoua	21.59	25.62	15.54	15.37	20.55	18.67
Bamenda	14.48	17.30	11.84	11.11	15.08	14.45
Bafoussam	13.14	15.21	10.81	10.22	13.86	12.51
Ebolowa	14.89	17.54	12.68	13.36	14.01	12.69
Buea	15.63	16.48	12.21	11.50	14.35	12.50

Table 5.9 Closeness values for regional capitals (Source: Author)

We observe a pattern that has not changed much over the years: Yaoundé has remained the regional capital with the higher centrality (lowest closeness), while Maroua and Garoua are located the most distant from the rest of the network. The most relevant change over time has been the increased centrality of Bertoua, which has passed from being the fourth furthest capital to becoming the second more central. As explained in previous chapters, this is due to the progressive completion, between 2005 and 2015 of the works to overlay the road from Yaoundé to Ngaoundéré via Bertoua.

Absolute changes in closeness are not providing conclusive information. As the transport network improves, travel times are reduced and, consequently, closeness centrality should be lower. However, comparing the absolute value between years would only be possible if the number of connected vertices remains constant. For example, in figure 5.6, the increase of the closeness index between 1995 and 2005 is because the network has incorporated more connected localities. As most of them are in remote areas, the average time to travel from a vertex to all the other vertices of the graph has increased.

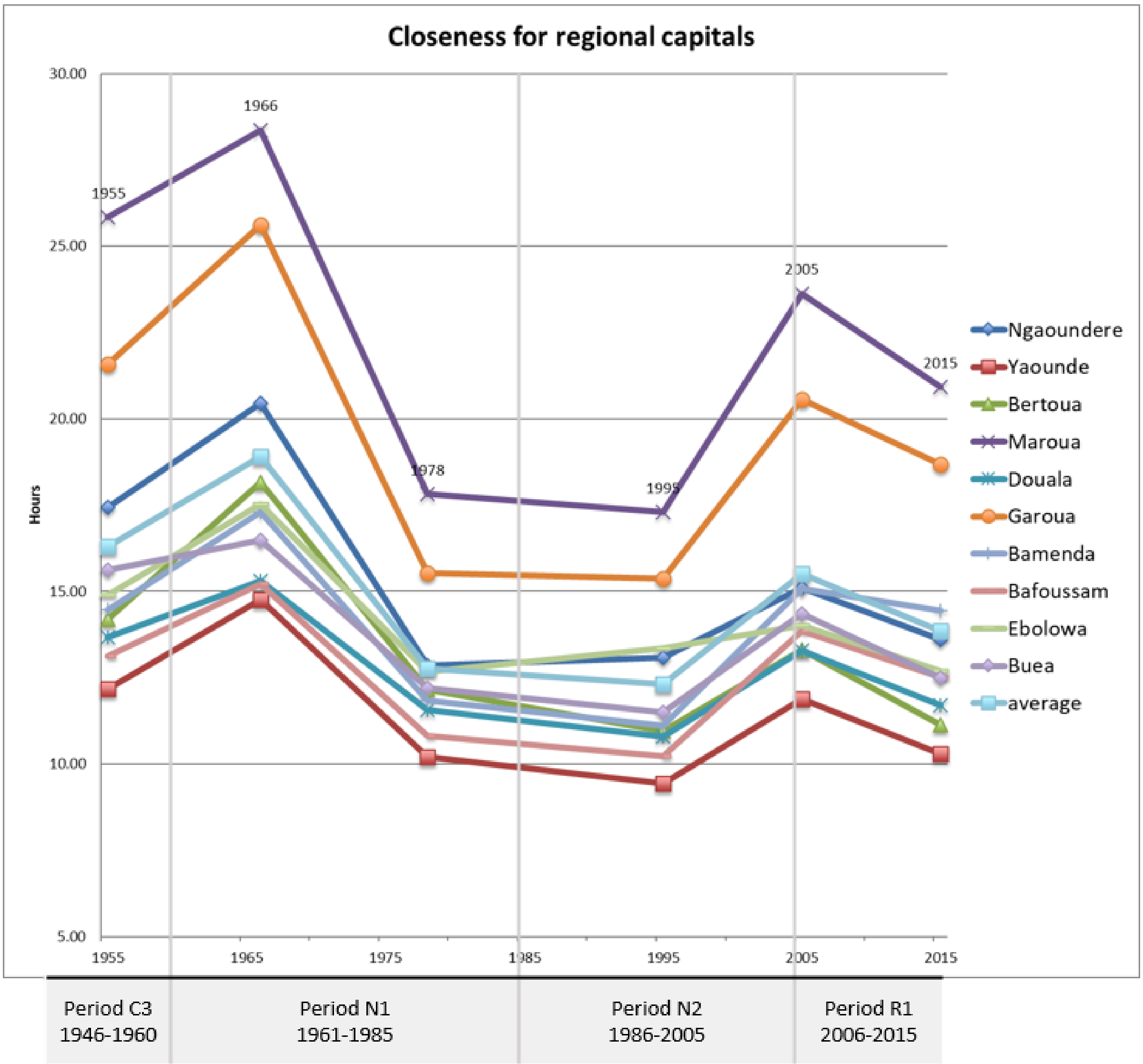


Figure 5.6 Evolution of the closeness index for regional capitals in Cameroon (Source: Author)

What is important in examining closeness over time is the relative increase of the closeness value between capitals. We want to know if some regions have worsened their position in the network relatively to others. As Yaoundé has always the lowest value, thus the highest centrality, we can assign to it a value of 0 and calculate the difference of closeness of all the other regional capitals in relation to Yaoundé (figure 5.7). The interpretation is straightforward. Since 1978, the cities of Maroua, Garoua, Bafoussam and Bamenda have progressively weakened their position in the network in relation to Yaoundé. Four other capitals, Douala, Buea, Ngaoundéré and Ebolowa, do not have significant changes and only one city, Bertoua, has improved its closeness centrality in relation to Yaoundé.

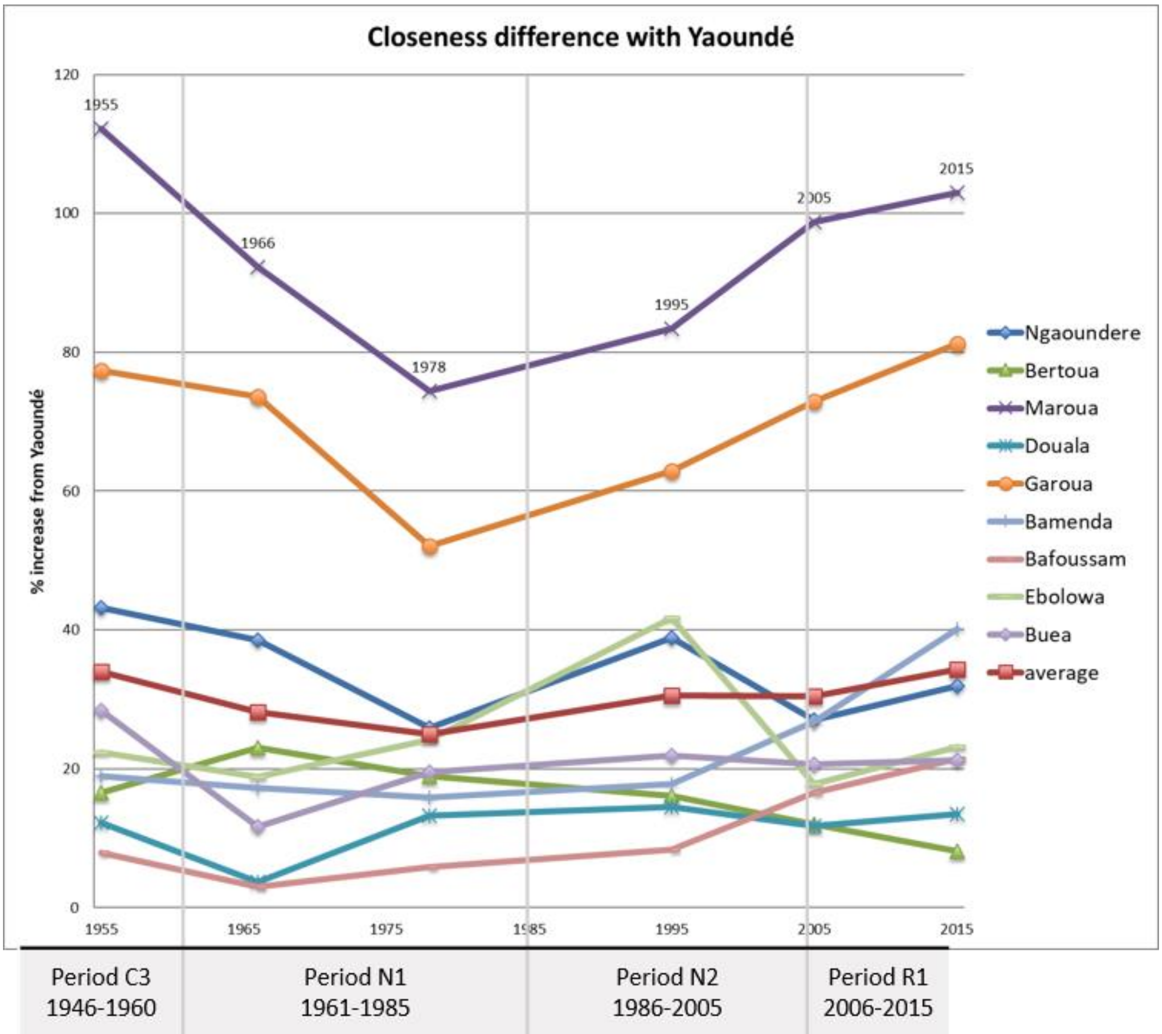


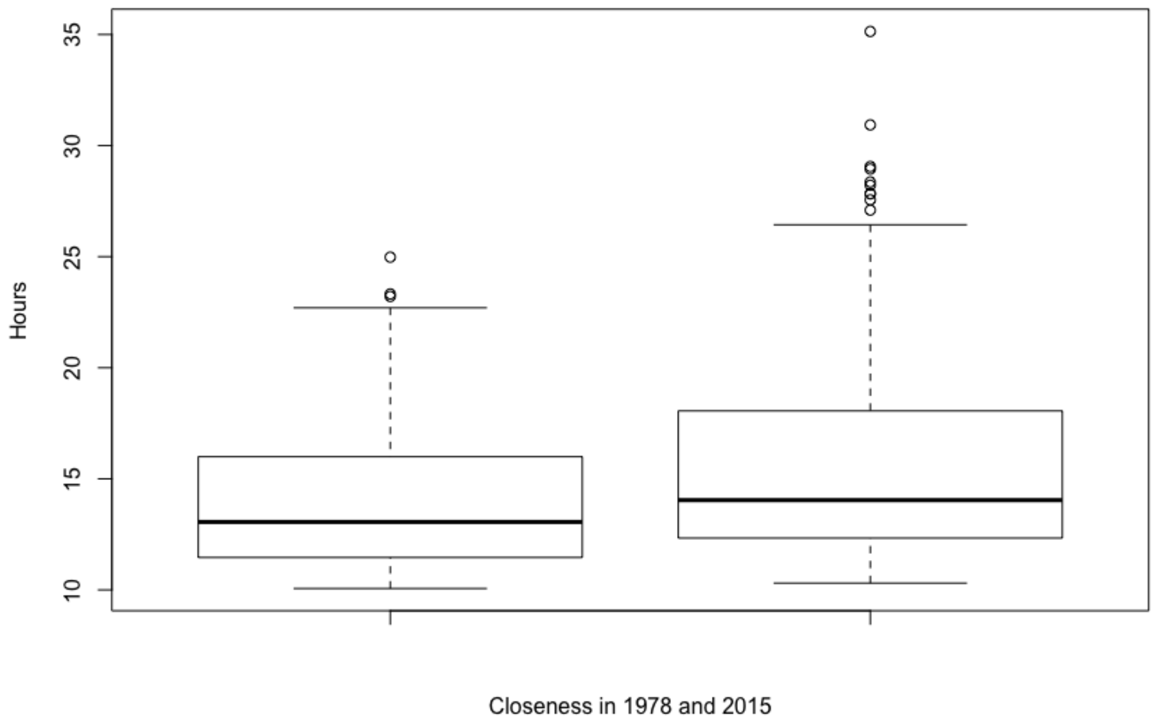
Figure 5.7 Relative closeness difference between the regional capitals and Yaoundé
(Source: Author)

A circumstance whereby, since 1978, some localities have worsened their closeness centrality in relation to the more central ones can also be observed from the standard deviation calculated for all the localities in the network (table 5.10). In 1978, the mean of the average time to reach all the localities of the network from any specific locality was 14.08 hours with a standard deviation of 3.24 hours. In 2015, the mean was 15.56 hours and the standard deviation increased to 4.52 hours.

	1955	1966	1978	1995	2005	2015
mean	16.97	19.95	14.08	13.58	17.24	15.56
sd	4.87	5.29	3.24	3.60	4.68	4.52

Table 5.10 Mean and standard deviation of the closeness values in different years
(Source: Author)

The increased spread of closeness distribution can be further explored by comparing the box plots in 1978 and 2015 (figure 5.8). We observe that the 2015 closeness is more strongly skewed towards higher values, with more numerous outliers and a maximum of 35.14 hours (while in 1978 the maximum was 24.98 hours). Between 1978 and 2015, 13 localities were added to the graph. It is difficult to establish if the increase of the mean and the median is due to the new localities or, as it happened between 1966 and 1978, the improvement of the network should have offset the addition of new vertices. What is clear is that, besides the outliers and the difference between the higher and the lower values, the interquartile range has increased, from 4.54 to 5.57 hours, which shows a more spread distribution.



	1978	2015
localities	286	299
min	10.06	10.31
1st quartile	11.46	12.33
median	13.06	14.04
3rd quartile	16.00	18.06
max	24.98	35.14

Figure 5.8 Box plots for closeness centrality in 1978 and 2015 (Source: Author)

In conclusion, the analysis of the closeness centrality shows that this indicator has intensified its spread over time, and in particular, between 1978 and 2015. This means that the network has become more unbalanced, exacerbating the bias towards the towns around Yaoundé and consolidating the capital as the best localisation in the network.

5.2.4. Betweenness centrality

The betweenness centrality of the urban centres has been calculated according to the definition given in section 3.2.3. In table 5.11, we have listed the localities with the highest betweenness values for each of the computed years. Betweenness centrality can be interpreted as a measure of the network resilience, as it indicates the impact of removing a vertex from the network. In the case of a locality with high betweenness centrality, the removal will imply longer geodesic paths. On top of it, if there are no alternative paths, the network splits into two or more disconnected subgraphs. This is the reason explaining the presence of the four localities Ngaoundéré, Mbe, Guidjiba and Pana among the top ten betweenness values since 1966. Indeed, they are located along the main route connecting the north and the south, the only acceptable option to link the two parts of the country.

1930	1955	1966	1978	1995	2005	2015
Ntui	Ngaoundéré	Ngaoundéré	Ngaoundal	Ngaoundal	Ngaoundal	Yaoundé
Batchenga	Yaoundé	Mbe	Ngaoundéré	Ngaoundéré	Ngaoundéré	Ngaoundéré
Yaoundé	Mbe	Guidjiba	Guidjiba	Guidjiba	Guidjiba	Guidjiba
Obala	Guidjiba	Pana	Mbe	Mbe	Mbe	Mbe
Boura	Pana	Tibati	Pana	Pana	Yaoundé	Pana
Matsari	Tibati	Doulayel	Ngong	Belabo	Pana	Ngong
Ndikinimeki	Doulayel	Ngong	Garoua	Batchenga	Ngong	Mekong
Yoko	Ngong	Garoua	Yaoundé	Ngong	Batchenga	Abong Mbang
Bafia	Garoua	Martap	Ebongo	Yaoundé	Garoua	Awae
Tibati	Obala	Beka	Nanga Eboko	Garoua	Belabo	Bertoua

Table 5.11 Localities with the highest betweenness value in the graph (Source: Author)

Figure 5.9 contains the planar graph for 2015 where we have indicated the localities listed in table 5.11, which are the ones that have had the highest betweenness centrality since 1930. We can differentiate for groups: 1) 1930, 2) 1955-1966, 3) 1978-1995-2005 and 4) 2015. As Yaoundé is present in the top ten betweenness for every year, we have not grouped it to simplify the map.

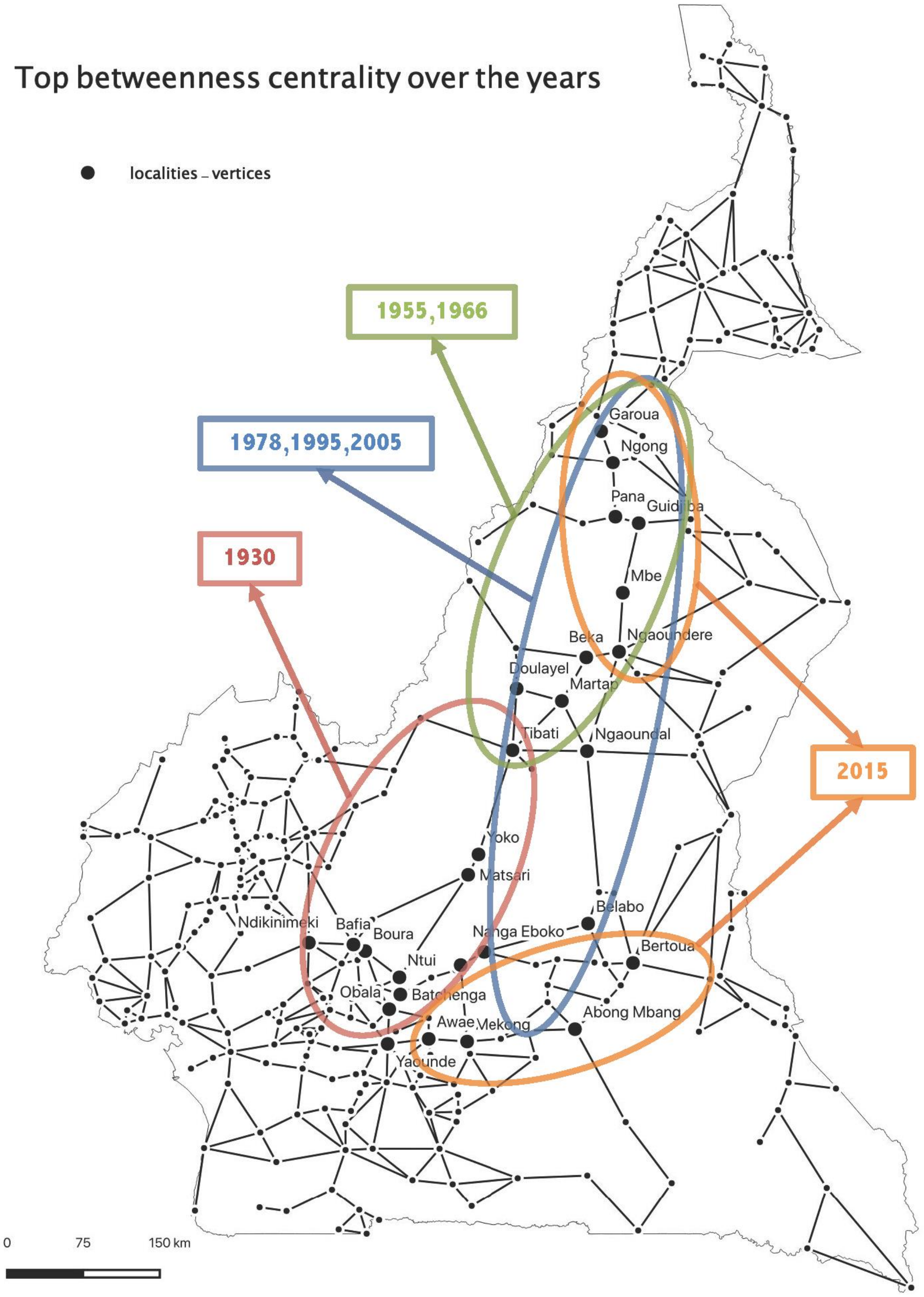


Figure 5.9 Planar graph for 2015 where the most central localities (highest betweenness values) have been marked and grouped by years (Source: Author)

Until 1966, the main link to connect the south and the north of the country was the road via Yoko and Tibati. This is the reason why the 1930 and 1955-1966 groups of localities are aligned along that road (red and green ellipses). With the construction of the railway, in the period 1978-2005, the centrality moved towards the east, with the localities of Nanga Eboko, Belabo and Ngaoundal becoming pivotal at that time (blue ellipse). Finally, the construction of the road Yaoundé-Bertoua-Garoua Boulai-Ngaoundére pushes further the centrality towards the east (orange ellipses). Moreover, the existence of two alternatives to reach the north, the road and the rail, makes that nodes in the Adamaoua region, like Yoko, Tibati or Ngaoundal, lose their condition of being decisive in terms of connectivity. As it can be observed, what remains constant since 1955, is the fact that the towns situated along the Ngaoundéré-Garoua road are of the utmost importance. In terms of betweenness centrality, it means that they act many times as bridges along the shortest paths between vertices in the south and vertices in the north of the country.

A similar analysis can be done by representing the edge betweenness over time (figure 5.10). As expected, in 1930, most of the shortest paths passed along the only link connecting the south and the north of the country via Yoko. In 1966, the two alternative routes in the west, via Foumban, and in the east, via Bertoua, had emerged. However, the central option remained the most used, followed by the itinerary through the west. At that time, we can also observe the importance of the links between Douala and Yaoundé and from Douala to Bafoussam. As can be seen, the end of construction work on the railway to Ngaoundéré in 1978 marks a major change in the centrality of the routes linking the south and north of the country. The betweenness values of the road via Yoko pronouncedly drops, while the west route is the most used one in addition to the one along the new railway. The links around Yaoundé reinforced their centrality. These characteristics of the network in terms of the most central routes and localities were kept until, at least 1995, as can be seen in the map. However, from 2005, we observe that the centrality of the network begins to shift eastwards. This, as we know, is due to the construction of the Yaoundé-Ayos and, later, Ayos-Bertoua roads. In that period, the link in the west, through Foumban and Bafoussam still retained a high degree of centrality. On the contrary, the road via Yoko continued to lose relative weight in relation to the rest of the network. Finally, 2015 marks the consolidation of the trend towards a concentration of the centrality of the network in the east of the country. This the result of completing the asphalt along all the sections Yaoundé-Bertoua-Garoua Boulai-Ngaoundéré. We observe how even the railway lost relative centrality to the benefit of the east road link, which is faster. Indeed, in 2015 the Trans-Cameroon railway II section was forty years old and was beginning to show signs of fatigue, requiring rehabilitation in several of its sections. In this situation, it was difficult to compete with a newly built road, especially in terms of passenger transport. In this last period, we observe that the west of the country remains highly central but losing weight in front of the Yaoundé-Douala and Yaoundé-Bafoussam links.

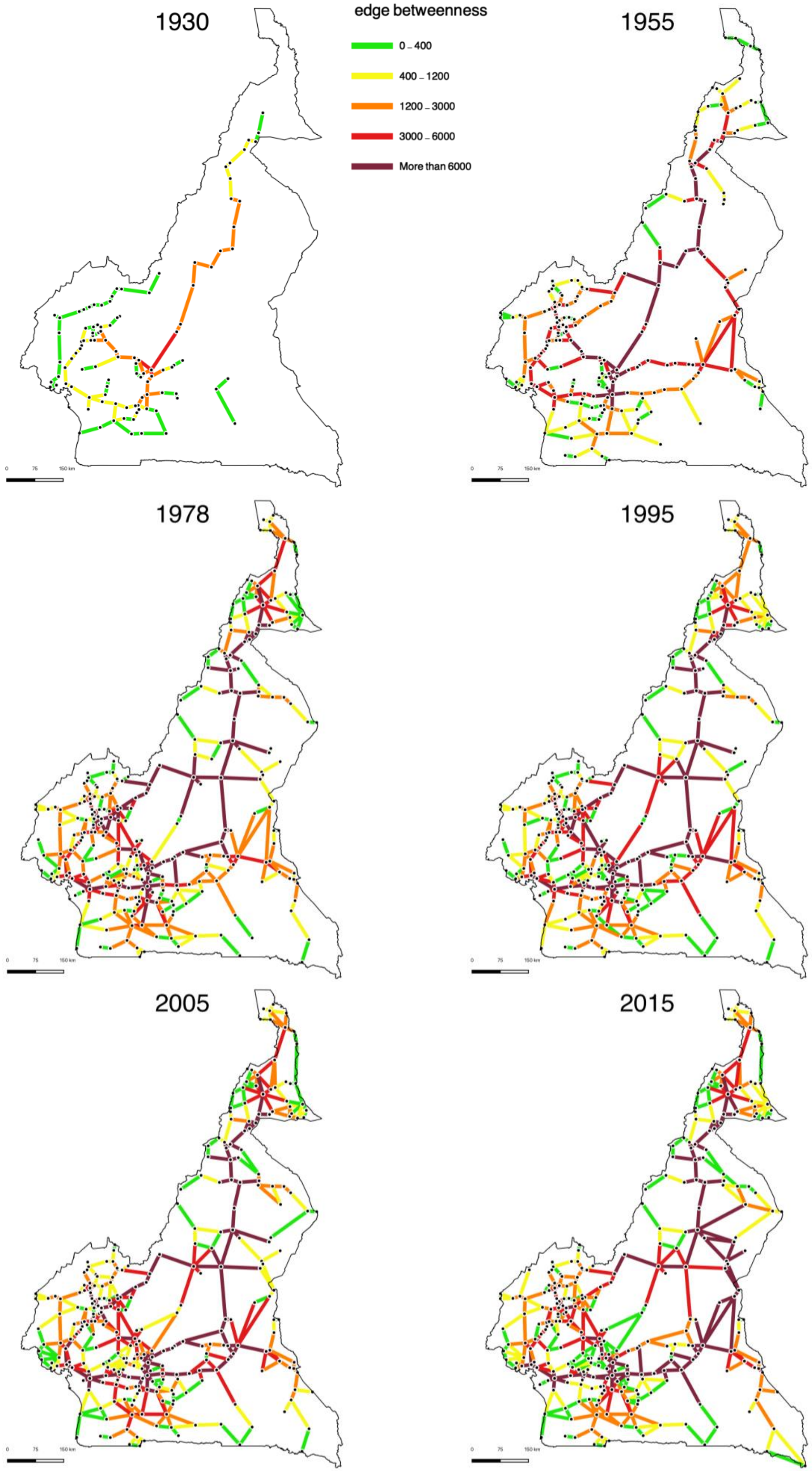


Figure 5.10. Edge betweenness in Cameroon 1930, 1966, 1978, 1995, 2005 and 2015 (Source: Author)

When analysing the evolution of the betweenness centrality of regional capitals, we observe a few relevant characteristics[93] (table 5.12 and figure 5.11). First, Buea, which is located at the end of a path, or close to it, has, as one can expect, a value close to zero, or even zero, in all the years. Then, the cities in the periphery of the graph with low centrality over time are Maroua, Ebolowa and Bamenda. On the other side, we have Ngaoundéré and Garoua that, through the years, have remained with high values of betweenness centrality, for the reason of acting as a bridge between the north and the south, as we have explained above.

	1930	1955	1966	1978	1995	2005	2015
Ngaoundéré	0.289	0.553	0.652	0.624	0.577	0.603	0.577
Yaoundé	0.448	0.552	0.392	0.414	0.415	0.488	0.593
Bertoua	-	0.274	0.233	0.132	0.164	0.187	0.421
Maroua	0	0.150	0.247	0.190	0.159	0.192	0.197
Douala	0.135	0.211	0.303	0.133	0.147	0.224	0.205
Garoua	0.168	0.443	0.533	0.431	0.401	0.421	0.409
Bamenda	0.029	0.258	0.203	0.133	0.137	0.142	0.128
Bafoussam	0.136	0.280	0.261	0.343	0.290	0.272	0.183
Ebolowa	0.016	0.111	0.083	0.079	0.060	0.099	0.068
Buea	0.012	0	0.001	0	0	0	0

Table 5.12. Normalised betweenness values for regional capitals (Source: Author)

Along with the capitals that have a stable betweenness index, we observe three with a significant change in trend over time. First, Bafoussam has been in constant decline since 1978, with a higher negative decrease between 2005 and 2015. It contrasts with the remarkable growth of Bertoua's betweenness centrality in the same period. As we have already indicated, this sharp increase of the relative importance of Bertoua in the network is due to the construction of the Yaoundé-Bertoua-Garoua Boulai-Ngaoundéré asphalted road. Finally, in line with previous findings, we observe the progressive

[93] In 1930, the graph was constituted by different subgraphs, hence the interpretation is more difficult. This analysis is based on the observations of the index from 1955.

improvement in the position of Yaoundé until becoming in 2015 the most unavoidable node in the network.

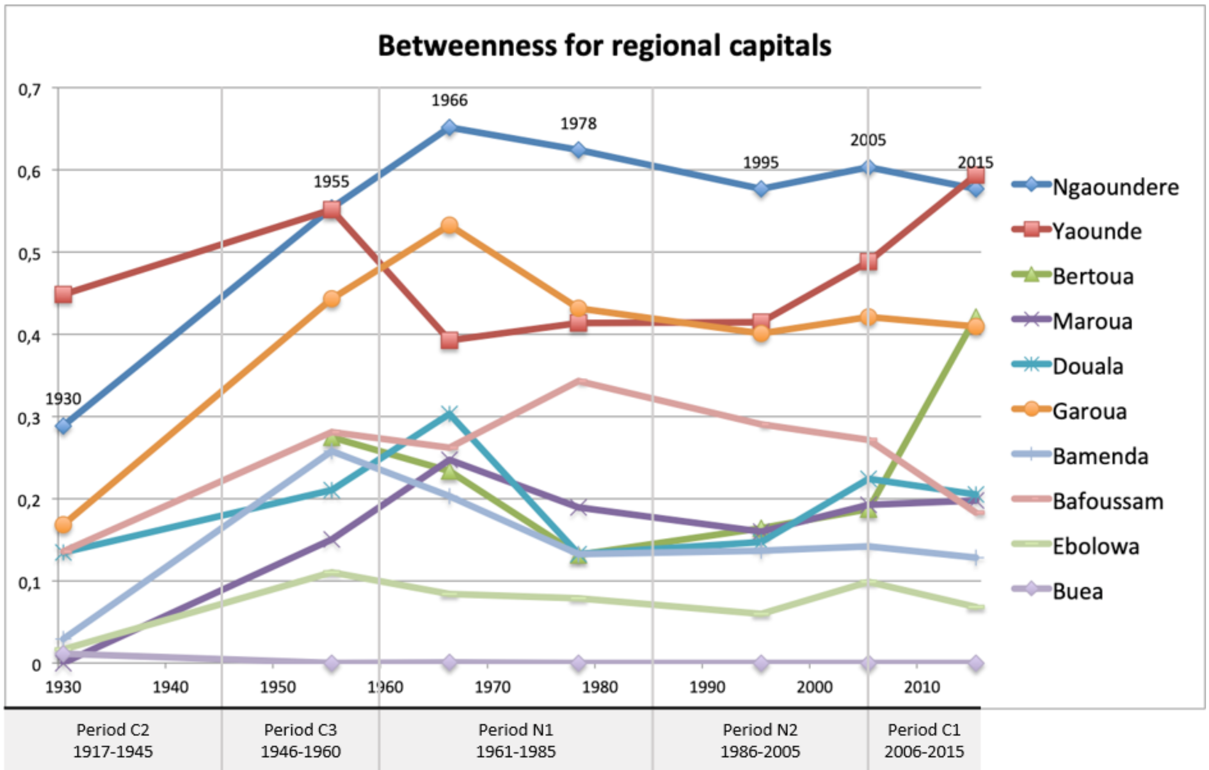


Figure 5.11. Evolution of the betweenness index for regional capitals in Cameroon (Source: Author)

The values of the betweenness-based measure of overall centrality calculated for the transport network in Cameroon are compiled in table 5.13 and represented in figure 5.12. They show a logical downward trend where, over the years, the addition of new links has improved the connectivity, that is, increased the possibility of having alternative paths between nodes and, therefore, reduced the risk of having critical highly central localities.

1930	1955	1966	1978	1995	2005	2015
0.884	0.340	0.399	0.307	0.284	0.271	0.262

Table 5.13. Betweenness-based measure of overall centrality over the years of the transport network in Cameroon (Source: Author)

The only exception is during the period 1955-1966. This worsening of the overall centrality indicator can be explained by the fact that the government was trying to cover the whole territory of Cameroon through an incipient but fragile expansion of the network. The newly constructed road links to the more remote areas of the country had no alternative and any disconnection, for example due to a collapsed bridge, flood, or landslide, would have meant isolation of the areas served. This vulnerability was progressively reduced in the following decades thanks to an increased connectivity.

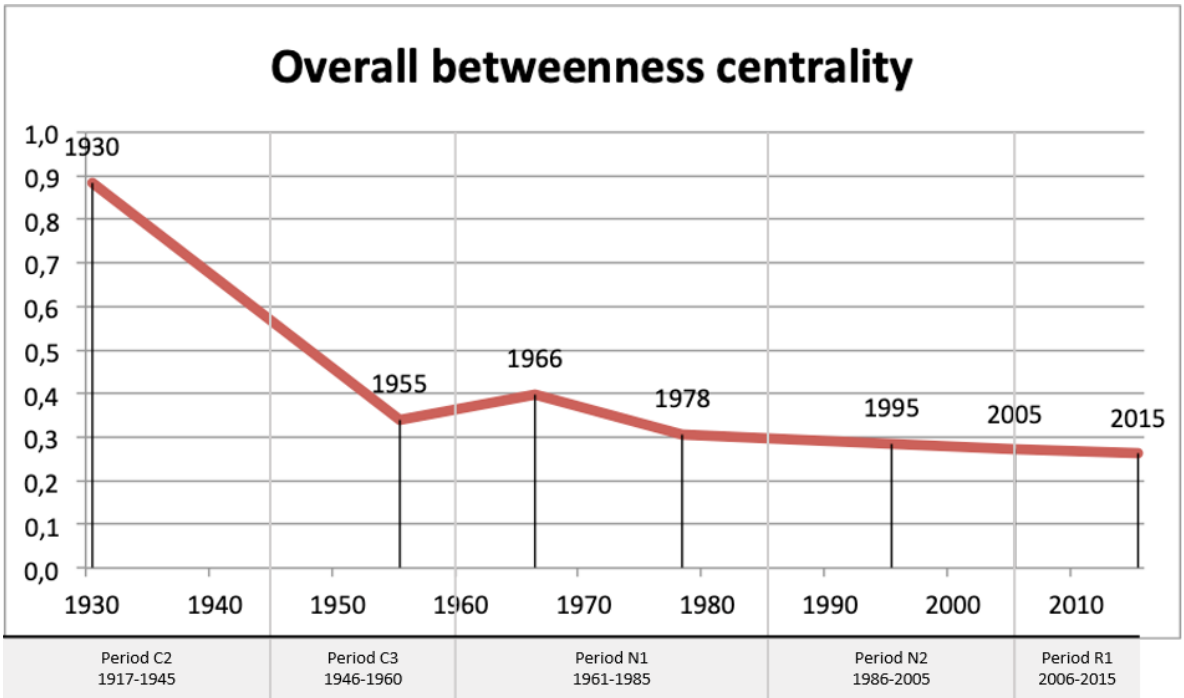


Figure 5.12. Overall betweenness centrality of the transport network in Cameroon
(Source: Author)

In conclusion, the analysis of the betweenness centrality when studying the development of the transport network in Cameroon shows that the country is progressively less reliant on travelling through some critical nodes. Accordingly, the network is more resilient. However, the section Nagoundére-Garoua remains critical. In addition, the unbalanced development of the network identified by previous indicators, is also captured by the betweenness index. The diminished importance of Bafoussam and the rise of Bertoua, illustrates this movement of the centre of gravity towards the east.

5.3. Conclusions of the structural analysis

The geohistorical analysis carried out in chapter 4 allows us to identify the periods of the network and to describe its main characteristics for each spatiotemporal paradigm. However, to understand how the executed network distances or approaches itself from the maximum network, it is necessary to characterise its evolution quantitatively. Table 5.14 summarises the trend of growth or decline of the main indicators of network efficiency and connectivity along the different periods. As explained above, the indicators can only be calculated when the network is well developed, i.e. from 1930 onwards.

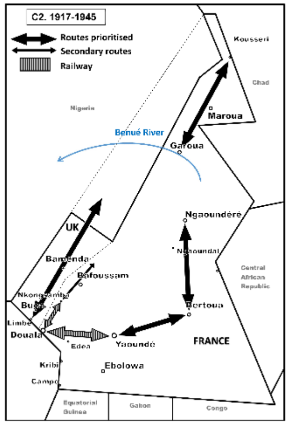
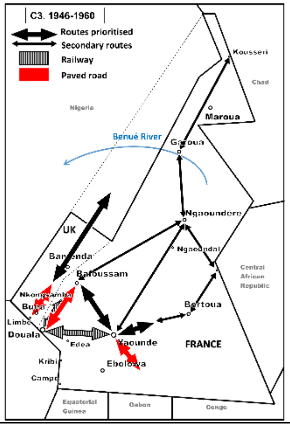
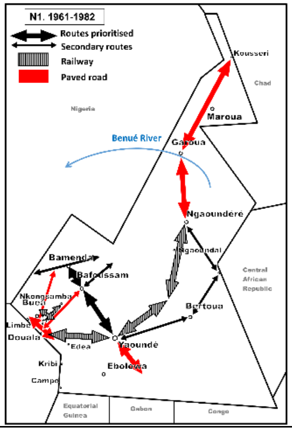
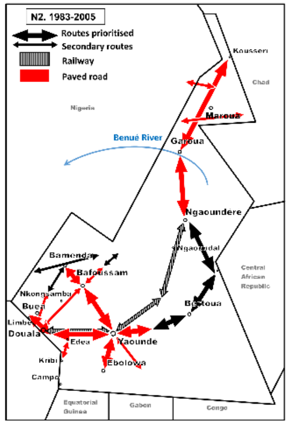
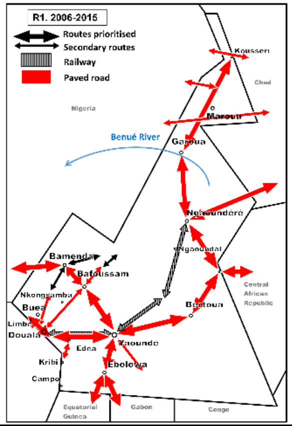
Period	C2	C3	N1	N2	R1
Years	1917-1945	1946-1960	1961-1982	1983-2005	2006-2015
Regime	French & British Mandate	French & British Trusteeship	National – President Ahidjo	National – President Biya	Regional – President Biya
Spatiotemporal network pattern	**Selection of penetration routes** 	**"Fertile crescent", the "useful Cameroon"** 	**Unification corridors** 	**Internal economic interconnection** 	**Regional corridors** 
Detour index	⇓	⇓	⇑	⇔	⇓⇓
Alpha	⇑	⇑	⇑⇑	⇔	⇑
Gamma	⇑	⇑	⇑⇑	⇔	⇑
GTP	⇑	⇑	⇑⇑⇑	⇔	⇑
Connectivity pattern	Tree	Tree	Tree, almost grid	Tree, almost grid	Grid
Lowest closeness	*Not applicable*	Yaoundé < Bafoussam < Douala	Yaoundé < Bafoussam < Douala	Yaoundé < Bertoua = Douala	Yaoundé < Bertoua < Douala
Overall relative closeness (Ydé)	*Not applicable*	⇓	⇓	⇔	⇑
Highest betweenness	Yaoundé > Ngaoundéré > Garoua	Yaoundé = Ngaoundéré > Garoua	Ngaoundéré > Garoua > Yaoundé	Ngaoundéré > Garoua = Yaoundé	Yaoundé > Ngaoundéré > Garoua = Bertoua
Overall betweenness	⇓⇓	⇑	⇓	⇔	⇓

Table 5.14. Summary of the growth or decline of the transport network structural indicators for each spatiotemporal pattern (Source: Author)

Firstly, it can be observed that, between the different periods, there are significant changes in the growth and decline trends of the network structure indicators. These changes confirm that the political, economic and social context of the identified periods has had a real impact on the development of the network, and therefore reinforces the approach adopted whereby six periods can be distinguished between 1884 and 2015.

The second period, from 1917 to 1945, is characterised by a slight increase in the parameters that determine the connectedness of the network (alpha, gamma and GTP), but which has a major impact on the accessibility of the nodes (betweenness). In other words, given that the network was still to be developed, the decision of the French and British Mandatary administrations to choose certain penetration routes had a significant structuring effect. It was at this moment that the first decisions were made that would lead to major discrepancies between the maximum network and the implemented network. In this way, the detour index started to decline immediately, because certain locations were already detoured. On the contrary, Yaoundé, Ngaoundéré and Garoua quickly became the towns with the highest level of centrality betweenness.

As we have seen, in period C3, from 1946 to independence, under British and French trusteeship, there was intense activity to develop infrastructure, with the bulk of investment concentrated on the most profitable areas closest to the coast. Quantitative data shows that, despite significant investments by FIDES, improvements in the efficiency of the network as a whole were small. In this third period, the trend of improving network connectivity continued, although the network was tree-shaped and still far from being considered as a grid. The investments translated into an improvement of the overall betweenness, which means the reduction of critical links. In this period, Yaoundé, Bafoussam and Douala were the closest nodes to the rest of the localities, while Yaoundé, Ngaoundéré and Garoua were the localities through which the highest number of shortest paths run (i.e., with the highest betweenness centrality). Although the detour index continued declining and Yaoundé was already at that time the most central city, we observe a decrease in the average relative closeness difference between the regional capitals and Yaoundé. This can be interpreted as a better distribution of investments, which are spread over the territory rather than centred in Yaoundé. Therefore, in this period the network implemented tended towards the maximum rather than diverging from it.

Topological indicators confirm that period N1, from 1960 to 1983, was the golden age of Cameroon's transport infrastructure. All connectivity indicators made a qualitative leap, in particular the GTP index, according to which the network could already be considered as a grid, i.e., it reached full connectedness (*connexité*). In fact, although according to Usui and Anami's criteria the network fails to be classified as a grid, it is only by a few hundredths of a point of the alpha and gamma indices. In addition to the significant growth of the network, a relevant finding obtained thanks to the nodal accessibility indicators is that, during this period, the implemented network converged towards the maximum one. Indeed, we observe that, it is the only moment in the Cameroonian history studied that the detour index increased, at the same time as the average relative closeness difference between the regional capitals and Yaoundé decreased. Therefore, we can conclude that during the first 25 years of independence, investments were evenly distributed throughout the territory. The only indicator that did not change in a favourable way was the overall betweenness centrality, which also grew, indicating an increased vulnerability of the network with critical links. This development is logical because many more localities were connected to the network.

Period N2 is the period corresponding to the economic crisis in Cameroon during which the structural adjustment plans were implemented. As might be expected, most connectivity indices stalled during these years. As we have seen in chapter 4, during this period, Cameroon's transport policies were at the mercy of the preferences of its development partners, who, faced with scarce financial resources, began to impose a regional agenda that allowed them to concentrate their financial support. It is at this point that the choice was made to develop the eastern route, which was the road from Yaoundé to Ngaoundéré via Bertoua and Garoua-Boulai. In terms of nodal accessibility, the period is characterised by the reinforcement of Yaoundé as a node of maximum centrality. A noteworthy fact is the emergence of Bertoua as one of the most central cities, both regarding closeness and betweenness centrality, despite its eccentric location in the east of the territory.

Finally, in period R1, from 2006 to 2015, two opposing trends can be observed. On the one hand, the grid pattern of the network was consolidated, as there was an improvement in the alpha, gamma and GTP connectivity indices. At the same time, however, there was a deterioration in access to the regional capitals compared to Yaoundé, which is manifested by an increase of the overall average relative closeness index. Above all, there was a serious drop in the detour index, which indicates a greater deviation from the more direct routes. Consequently, the discrepancy with the maximum network was amplified. The tendency to concentrate on a single route through the east meant that the overall betweenness index continued to fall, which is logical as the network became more vulnerable due to fewer redundancies. As was to be expected, given the configuration of the network, the city of Bertoua established itself as one of the best connected cities after Yaoundé, in terms of both closeness or betweenness centrality.

6. Territorial analysis of infrastructure provision

In the previous chapter we analysed the network without considering population distribution or demographic trends. In this one, we will analyse the network with respect to population density at the regional level and taking into account where the main urban centres are located. The aim is to analyse whether investments in transport infrastructure have been made where the population lives or whether other criteria have been contemplated. We are also interested in the socio-economic reality of the population and try to correlate this with the provision of asphalt roads.

6.1. Densities of population and evolution of the network

Table and figure 6.1 indicate the values and the progression of the population density for the regions[94]. For the departments, we have opted to illustrate the evolution through the maps contained in figure 6.2. At regional level, the four regions with the highest density are the Littoral, the Ouest, the Nord-Ouest and Extreme-Nord. As we have seen in section 4.1, this population concentration along the regions bordering Nigeria existed prior to the German occupation. Thanks to figure 6.1, we observe, from 1985 (period N2 onwards), two regions with higher growth rates compared to the rest, the Littoral and the Extreme-Nord. In both cases, natural growth is augmented by rural-urban migration, and, in the case of the Extreme-Nord, there is a significant transboundary migration towards the main urban centres (Zieba, 2014).

	surface (km2)	1955	1967	1976	1987	2005	2015
Adamaoua	62,965	2.83	3.46	5.71	7.86	14.04	19.07
Centre	68,222	8.71	12.34	17.25	24.21	45.41	60.97
Est	109,741	1.79	2.50	3.34	4.71	7.03	7.61
Extreme-Nord	34,337	22.62	28.05	40.62	54.04	90.63	116.29
Littoral	20,286	17.55	29.99	46.10	66.69	123.70	165.39
Nord	66,751	4.08	4.55	7.18	12.47	25.29	36.59
Nord-Ouest	17,305	24.80	39.50	56.66	71.50	99.91	113.76
Ouest	14,013	39.50	55.90	73.90	95.61	122.70	137.13
Sud	49,061	4.40	5.34	6.42	7.62	12.94	15.28
Sud-Ouest	25,129	12.88	19.84	24.69	33.35	52.37	61.81
TOTAL	467,809	8.33	11.62	16.38	22.43	37.33	47.41

Table 6.1. Population density in Cameroon through the years (persons per km2)
(Source: Author based on public statistics)

[94] Since the statistical data we have obtained is in French, in this chapter we have kept the names of the regions in French. In this way, Est = East, Extreme-Nord = Far-North, Nord = North, Nord-Ouest = North-West, Ouest = West, Sud= South and Sud-Ouest = South-West.

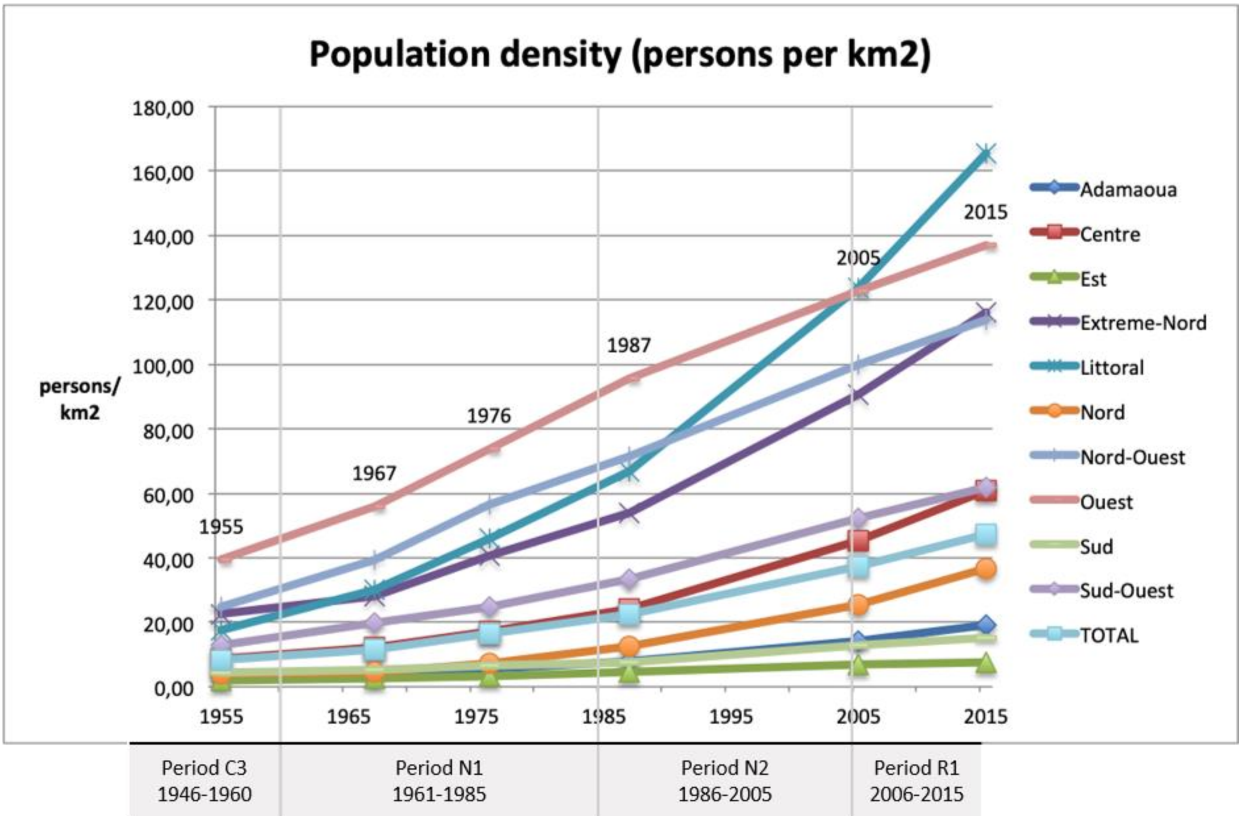


Figure 6.1. Evolution of the population density in Cameroon (Source: Author)

In figure 6.2, we have represented for the different years studied, the population density per department, being the higher values the ones with a darker green, and we have superimposed the transport network. The population density in 1967 is mapped with the network in 1966, the one in 1976 is superimposed with the roads and railways in 1978 and the population density in 1987 with the network in 1995. For the rest, the dates of the data population and the mapping of the transport network coincide.

Looking at the evolution of the density, we clearly identify the four areas where most of the Cameroonian population live: 1) on the coast around Douala and Buea; 2) in the western grassfields, where the current capitals are Bamenda and Bafoussam; 3) in the Extreme-Nord, in Maroua and its neighbouring localities; 4) and in Yaoundé and its surroundings. It should be recalled that while the first three areas were already densely populated when the Germans arrived, the densification of the Yaoundé area is the result of the relocation of the capital. While not empty, the rest of the country has remained with comparatively low densities.

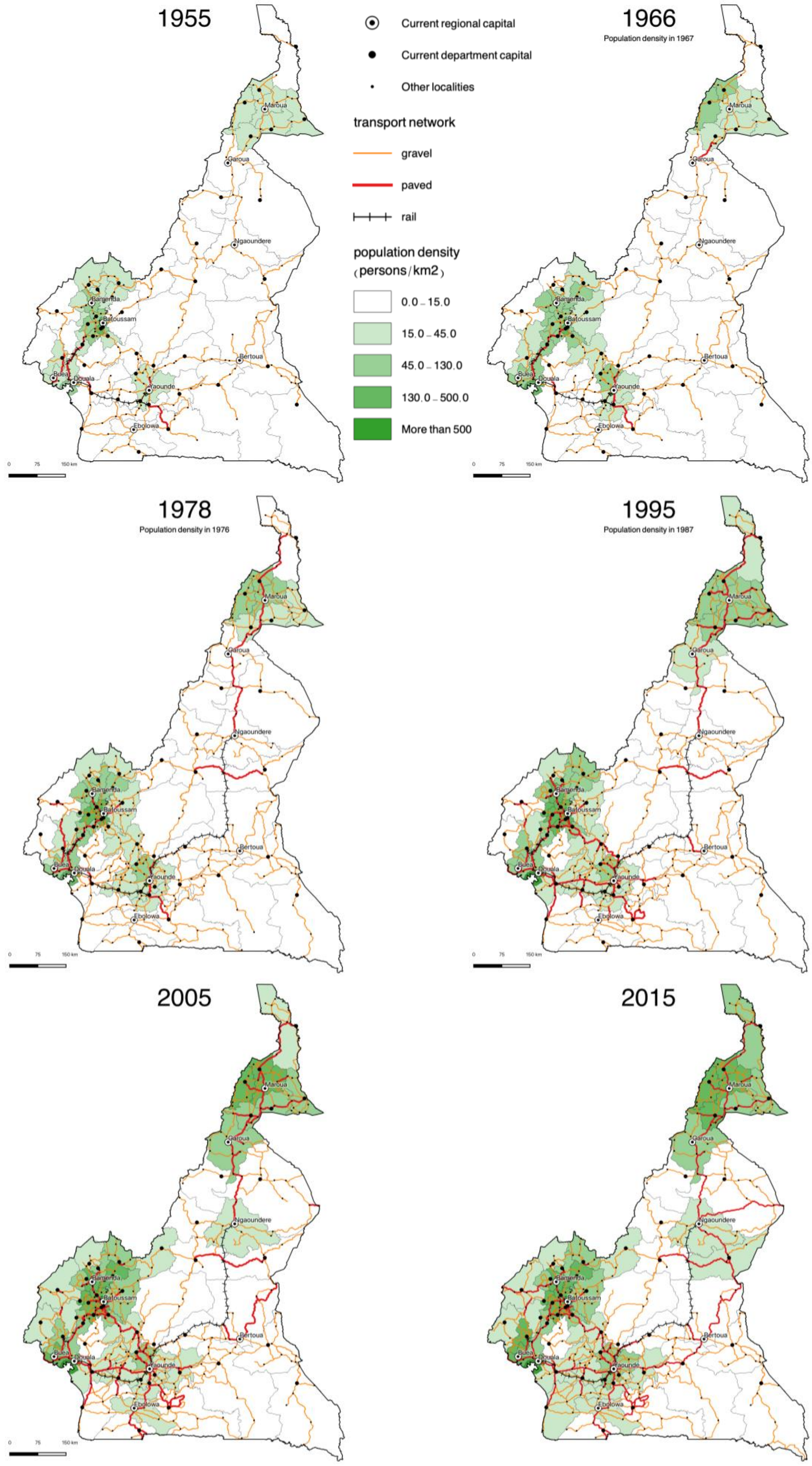


Figure 6.2. Evolution of the population density at department level and of the transport network (Source: Author)

What is interesting about these maps is to be able to analyse how the transport network has developed in relation to population density. The first observation is the enormous distance through very low-density areas between the coastal south-west of the country and the Sahelian north. As described in the section on historical development, linking these two parts of the territory was a great concern, first, for the German and French colonial powers and, later, for the new federal state of Cameroon. Secondly, we note that vast areas in the central savannas and rainforests of the southeast have remained virtually uninhabited.

Regarding the development of asphalt roads, we observe different patterns. First, they develop along the triangle Yaoundé-Douala-Bafoussam/Bamenda with a concentration of paved roads around these main cities connecting other dense urban areas located nearby. This radial expansion of paved roads from the main urban centres also happens in the case of Maroua. There are some exceptions to this growth of asphalted roads around the most populated areas. One is the road to Sangmelima and the ring going to Meyomessala that can be observed from 1995 in the South. As we have seen, this road was already asphalted in 1955 to feed the railway in Mbalmayo, with rubber and other forest products. Later, it was maintained and extended because it serves the village where the President Paul Biya was born. Another one is the road to Kribi that, although not substantially populated, has become the most important town on the coast for national tourism.

The second trend that can be observed is the development of roads to connect Yaoundé with the peripheral regions and neighbouring countries. These roads have in common that they do not go necessarily through the most densely populated areas. This is the case of the road from Ngaoundéré up to Kousseri that was asphalted to give continuity to the Trans-Cameroon railway. Under the same regional logic, the road from Yaoundé through Ebolowa to the borders with Equatorial Guinea and Gabon was paved (as it can be observed in the maps from 2005 onwards). Finally, we note the construction of the asphalted road Yaoundé-Bertoua-Ngaoundéré giving access to the Central African Republic. There are very few exceptions to this general rule of asphalting roads going radially towards Yaoundé that, in addition, are not going through populated areas. The most striking is the section of the Trans-African Highway in the Adamaoua, intersecting with the railway in Ngaoundal along a low densely populated region. As we have seen in section 4.2.3, in the 1970s, there was a weak economic justification to asphalt this road. Actually, it has remained many years isolated from the rest of the paved network. We also note a small section to connect Bertoua with the railway station of Belabo. This link has become important also to transport goods from/to the Central African Republic. More recently, we observe the construction of the road Ngaoundéré-Touboro-Moundou, connecting the south of Chad with Cameroon. This represented a novelty in the sense that it was not conceived under the logic of an internal transport system, but rather a regional one.

In conclusion, not surprisingly, paved roads that were mainly constructed in Cameroon in periods N2 and R1 concentrate where there is more population. Most of them are located along the Yaoundé-Douala-Bafoussam/Bamenda triangle. However, when it comes to connecting to peripheral regions and neighbouring countries, decisions have had to be made about the best routes to take, most of which go through regions sparsely populated. Asphalting these roads over long distances implies important investments where economic returns in the short term are not guaranteed, as traffic will remain low and basically of transit nature. As we have seen, decisions are often driven by political motivations, to unite the country and symbolically ensure the presence of the State in the most remote areas by linking them to the capital Yaoundé. The question is whether the adopted options are the optimal ones. In the next sections, we will continue to enquire about it.

6.2. Infrastructure provision over time

Compared to other African countries, the density of the network is low. It went from 9.85 km per thousand km^2 in 1930 to 47.44 in 2015 (figure 6.3). According to the World Bank, the average road density in Africa was 204 kilometres of road per thousand km^2 in 2010 (Gwilliam, 2011). Yet, in Cameroon, the density values can be misleading because, as we have said in precedent chapters, official figures do not include tens of thousands of kilometres of local rural and urban roads (with both earth and asphalt surface).

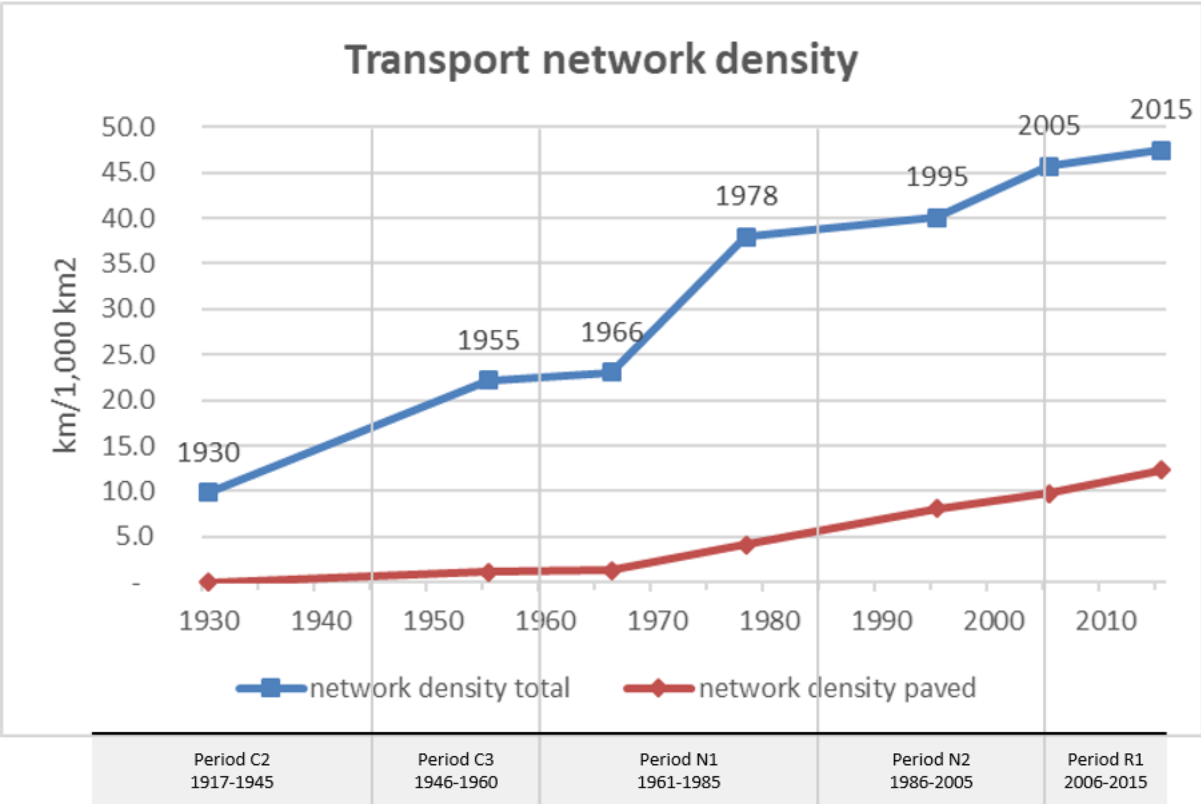


Figure 6.3. Evolution of the transport network and road network density in Cameroon (Source: Author)

In terms of km per thousand people, the network supply decreased from 1.64 km per thousand people in 1930 to 0.95 in 2015. Road supply on the continent is 3.4 km per thousand people, which is already less than half of the global average (Gwilliam, 2011). For instance, in Europe, road density is about 8.1km per thousand people according to Eurostat.[95] However, there is nothing extraordinary about the fact that network supply, in terms of kilometres per inhabitant, decreases over time. It would happen in any country that has reached full connectedness and has high rates of population growth. What is important is to look at how demographics evolve by regarding at the same time at the expansion of the transport network. In figure 6.4, we have superimposed the chart showing the evolution of the network in kilometres and population growth. In balloons, we have indicated the average annual growth between two mapped years. It is important to note that, when superimposing two graphs with different scales on the Y-axis, and with years on the X-axis, the slopes of the lines do not correspond to the percentage indicated.

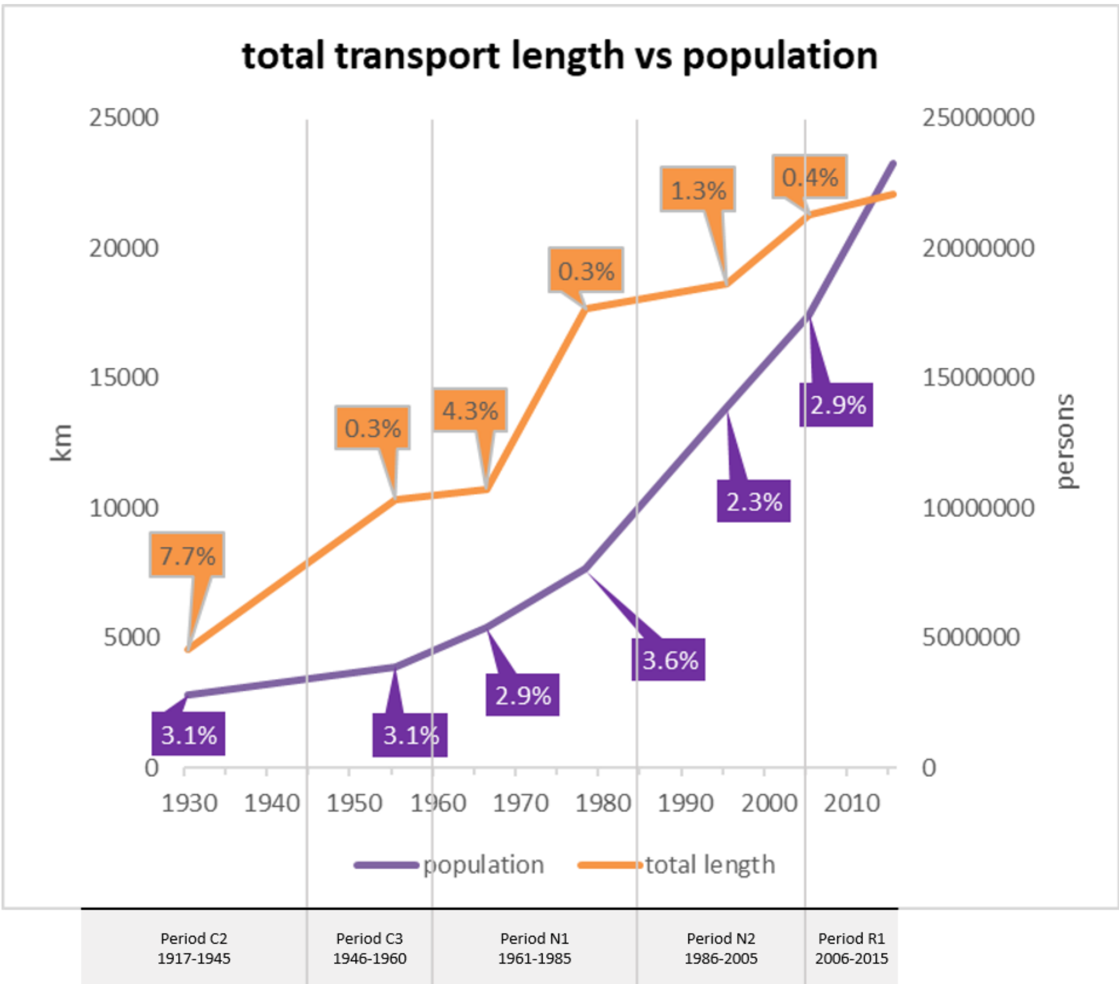


Figure 6.4. Joint visualisation of the transport network expansion in relation to population growth (Source: Author)

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[95] Eurostat, Inland transport infrastructure at regional level, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Transport_statistics_at_regional_level#Road_transport

We observe that, from 1978, the expansion of the network tends to slow down while the population growth rate follows an exponential shape. As we have seen in previous sections, in period N1, the flattening of the curve can be explained by the fact that the Cameroon network is close to reaching full connectedness (i.e., all the localities in the country are connected and it follows a grid pattern). However, it is probably not enough. In view of the strong population growth, the network needs to increase its connectivity by creating alternative routes. It will reduce the vulnerability of the network and prevent bottlenecks in the routes with higher traffic.

6.2.1. Network density by surface area and by population

The absolute lengths of the transport network for each region are indicated in table 6.2. These values are represented in the chart in figure 6.5. The Centre, where the capital Yaoundé is located, clearly stands above all the other regions as the one having the most transport infrastructure, followed by the Est. At the other end, with the lowest infrastructure endowment we find the Nord-Ouest and the Sud-Ouest, which are the Anglophone regions. Besides, we appreciate the stagnation of some regions in the last decades, as is the case of the Adamaoua, Littoral and Sud-Ouest. However, as we have said at the beginning of this section, to conduct the analysis of infrastructure provision, we need to look at the relative density values in relation to both the surface and the population.

	1930	1955	1966	1978	1995	2005	2015
Adamaoua	568	1,294	1,294	2,044	2,103	2,107	2,239
Centre	1,454	2,105	2,214	3,332	3,573	3,995	4,011
Est	181	1,341	1,341	2,581	2,649	2,951	3,100
Extreme-Nord	58	902	1,038	1,859	1,893	2,330	2,330
Littoral	547	894	969	1,586	1,426	1,429	1,500
Nord	347	836	871	1,455	1,705	2,094	2,267
Nord-Ouest	266	649	649	808	994	1,032	1,044
Ouest	370	553	570	1,165	1,175	1,480	1,480
Sud	468	1,180	1,180	1,966	2,121	2,656	2,674
Sud-Ouest	331	575	602	885	1,017	1,215	1,463
TOTAL	4,590	10,330	10,729	17,681	18,656	21,287	22,107

Table 6.2. Length of the transport network per region (km) (Source: Author)

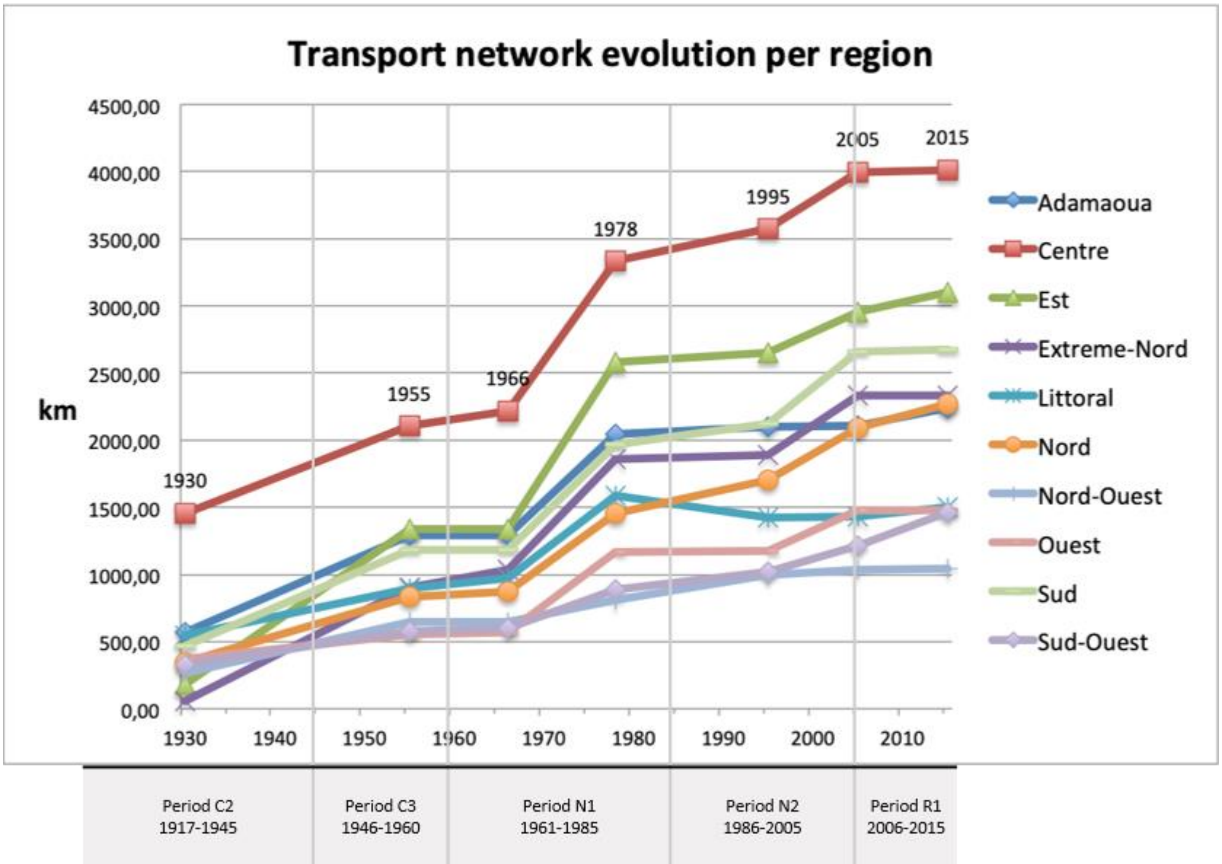


Figure 6.5. Evolution of the transport network per region (Source: Author)

In table 6.3, we provide the values over the years of the transport infrastructure by surface area for the different regions. The increase of this indicator is represented in figure 6.6. The region with the lowest infrastructure density over the years is the Est, which is also the largest one. At the other end, the Ouest stands out as the region having by far the highest network density, even compared with other smaller regions such as the Nord-Ouest and the Littoral. Despite these two extremes, and an unequal provision that has persisted over the years, the order of magnitude along regions is similar.

	surface (km2)	1930	1955	1966	1978	1995	2005	2015
Adamaoua	62,965	9.02	20.55	20.55	32.46	33.40	33.46	35.56
Centre	68,222	21.31	30.85	32.46	48.85	52.37	58.55	58.79
Est	109,741	1.65	12.22	12.22	23.52	24.13	26.89	28.25
Extreme-Nord	34,337	1.68	26.27	30.24	54.13	55.12	67.84	67.84
Littoral	20,286	26.95	44.08	47.79	78.19	70.28	70.43	73.93
Nord	66,751	5.20	12.52	13.05	21.80	25.55	31.37	33.96
Nord-Ouest	17,305	15.36	37.49	37.49	46.68	57.46	59.62	60.31

Ouest	14,013	26.44	39.47	40.68	83.14	83.88	105.63	105.63
Sud	49,061	9.55	24.06	24.06	40.07	43.22	54.13	54.51
Sud-Ouest	25,129	13.18	22.90	23.94	35.21	40.48	48.35	58.21
mean		*13.03*	*27.04*	*28.25*	*46.40*	*48.59*	*55.63*	*57.70*
sd		*9.40*	*10.89*	*11.68*	*20.86*	*19.17*	*23.22*	*22.62*
TOTAL	467,809	9.85	22.16	23.02	37.94	40.03	45.68	47.44

Table 6.3. Transport network density (km of infrastructure per 1000 km2) (Source: Author)

Looking at figure 6.6 and to the maps in figure 6.7, we observe an outstanding growth of the transport infrastructure in the Ouest region. Other features that can be highlighted is the stagnation of some regions, such as the Littoral, the Nord-Ouest and the Adamaoua. In the case of the Littoral there was even a contraction between 1978 and 1995 due to the dismantlement of the railway from Douala to Nkongsamba. Overall, we note that in the forty years until 2015 (periods N2 and R1), the network has not densified much. As we have discussed in previous sections, the challenge is less to expand the network but to offer a better service by asphalting the roads.

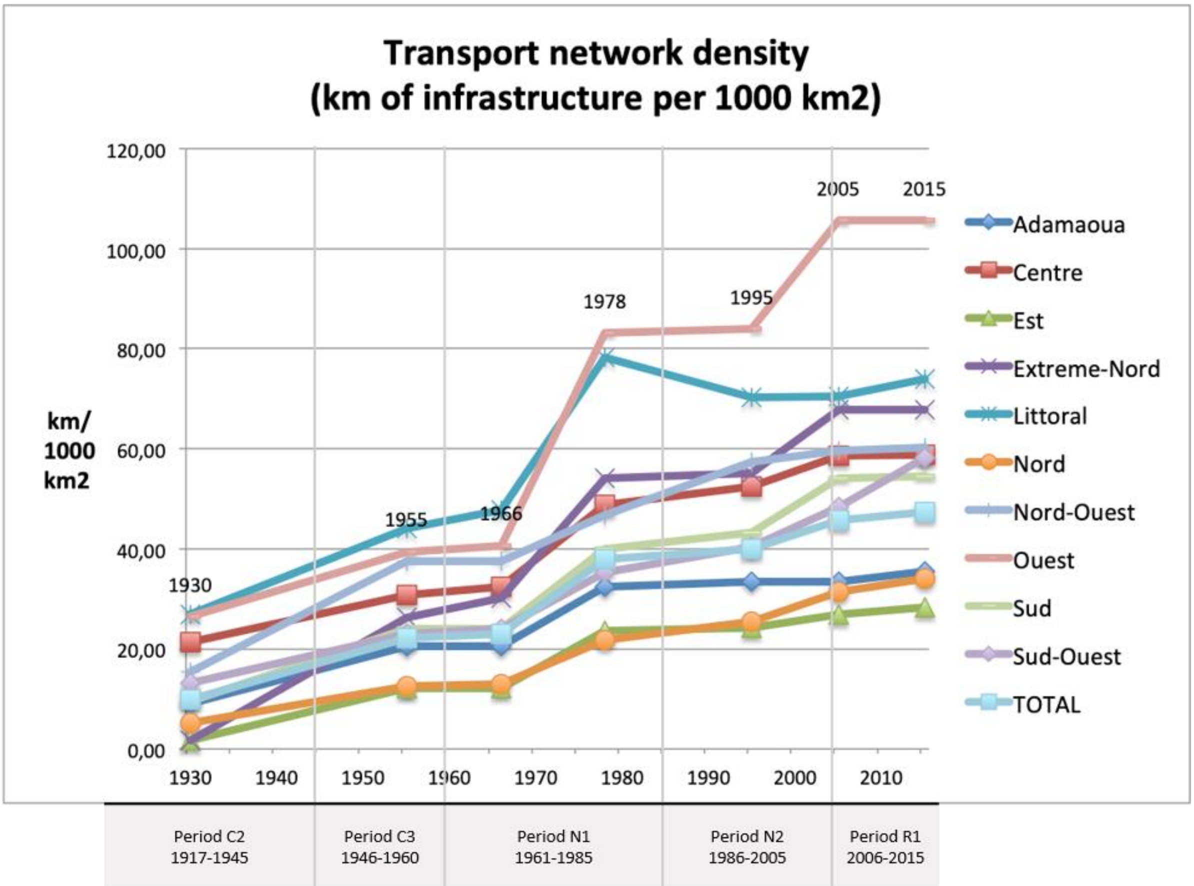


Figure 6.6. Evolution of the transport network density per surface of the regions (Source: Author)

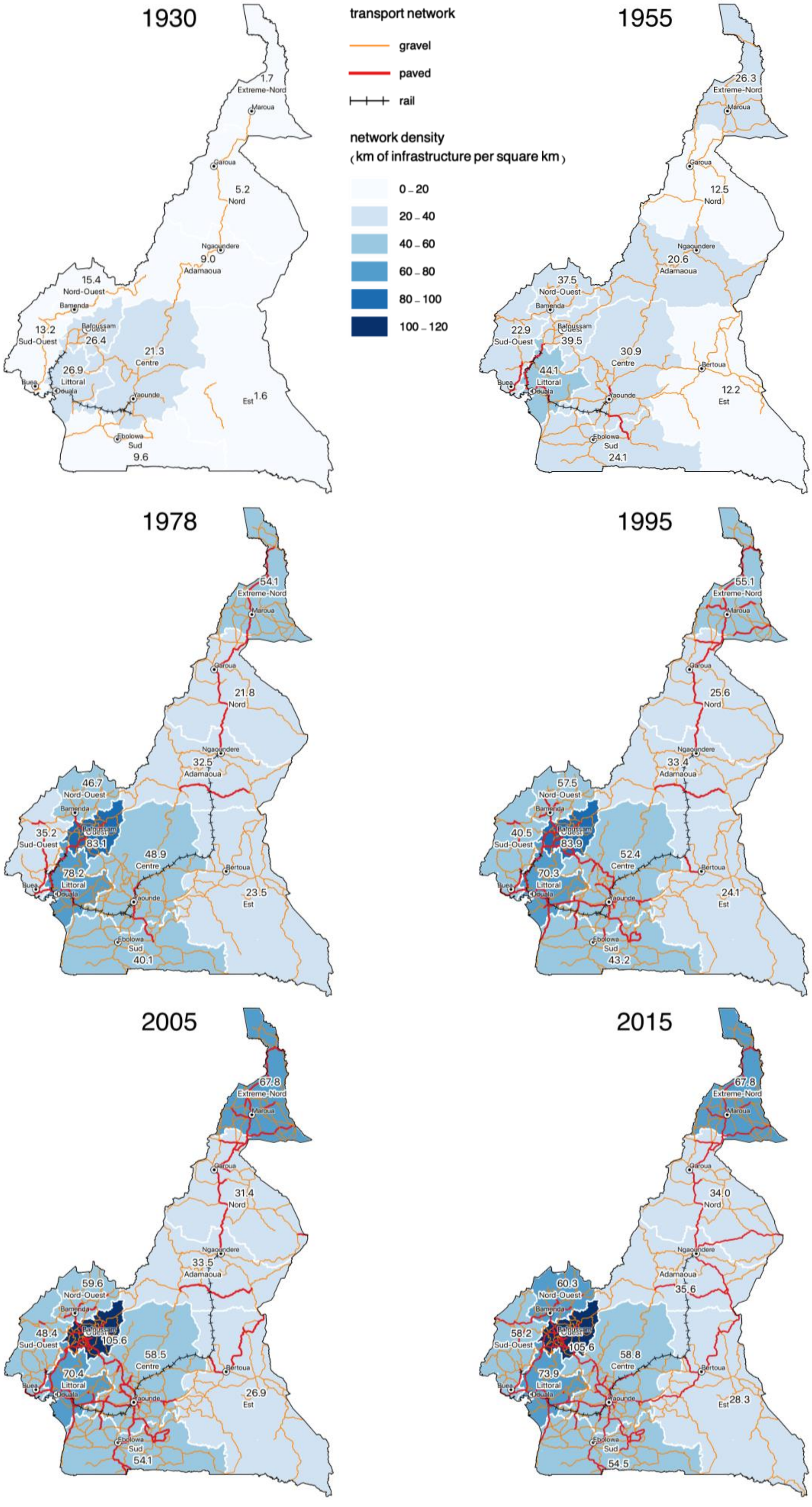


Figure 6.7. Maps showing the evolution of the transport network density per surface of the regions (km of infrastructure per km2) (Source: Author)

When the infrastructure provision is calculated on the population, the values decrease over the years, which is a normal trend in any country. As we have commented in previous chapters, Cameroon reached full connectedness (*connexité*) in the late 1970s, so it is logical that, from then, as the population is naturally increasing, infrastructure provision per person is declining. The figures showing this evolution are contained in table 6.4 and illustrated in the chart in figure 6.8 and the maps of figure 6.10. The only period where this indicator grows is in the 1960s and 1970s (period N1) as a result of the efforts to expand the network to unconnected areas, that is, the Government's search for complete connectedness of its territory.

	1955	1966	1978	1995	2005	2015
Adamaoua	7.26	5.95	5.69	4.25	2.38	1.86
Centre	3.54	2.63	2.83	2.16	1.29	0.96
Est	6.81	4.90	7.05	5.12	3.82	3.71
Extreme-Nord	1.16	1.08	1.33	1.02	0.75	0.58
Littoral	2.51	1.59	1.70	1.05	0.57	0.45
Nord	3.07	2.87	3.04	2.05	1.24	0.93
Nord-Ouest	1.51	0.95	0.82	0.80	0.60	0.53
Ouest	1.00	0.73	1.12	0.88	0.86	0.77
Sud	5.47	4.50	6.24	5.67	4.18	3.57
Sud-Ouest	1.78	1.21	1.43	1.21	0.92	0.94
TOTAL	2.65	1.97	2.31	1.34	1.22	0.95

Table 6.4. Transport network density (km of infrastructure per 1000 persons) (Source: Author)

Once Cameroon has reached reasonable levels of connectedness, we need to look, not only at the levels of connectivity (whether it is a tree, a grid or a delta configuration, as we have seen in the previous chapter), but also at the quality of the service provided by the existing links. It is not the same having such connectivity on gravel roads as on paved roads. We observe that, from 1978, density stops growing and stands at around 0.25km/1000 inhabitants (figure 6.9). Taking into consideration the initial infrastructure scarcity and the emerging economic development needs, the length of inter-urban asphalt roads may not be increasing enough to provide a satisfactory service to the country.

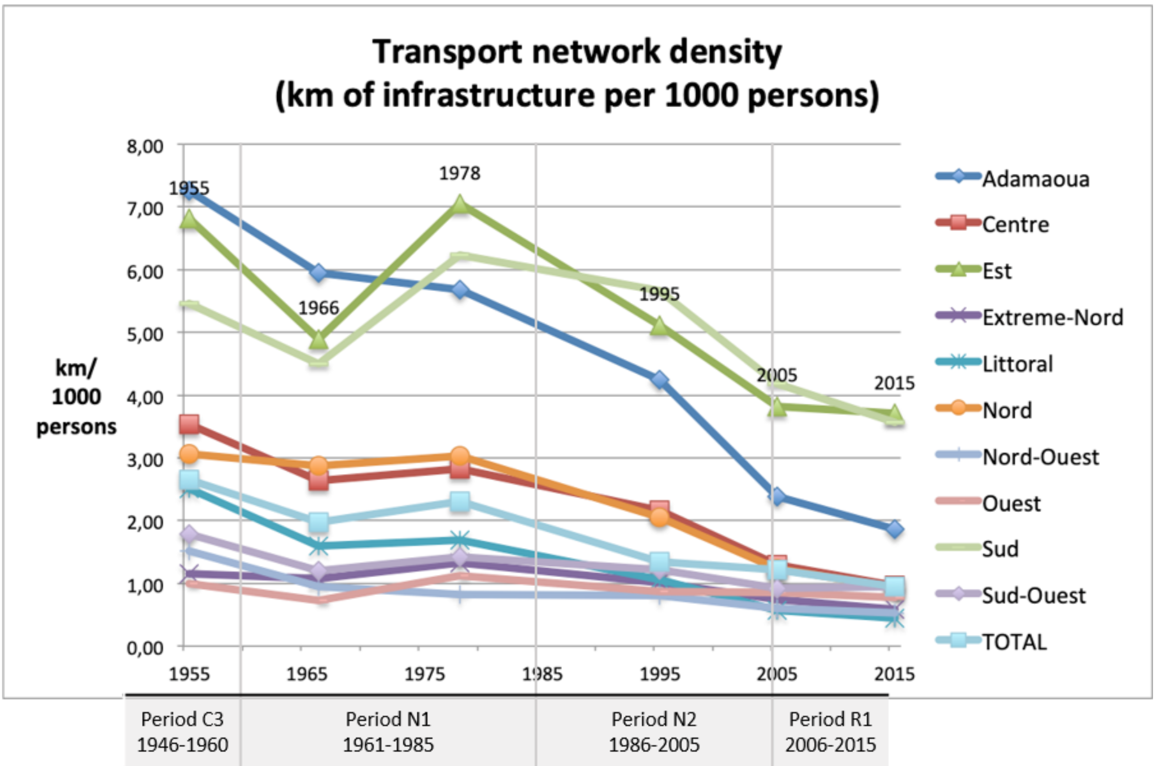


Figure 6.8. Evolution of the transport network density per population of the regions (Source: Author)

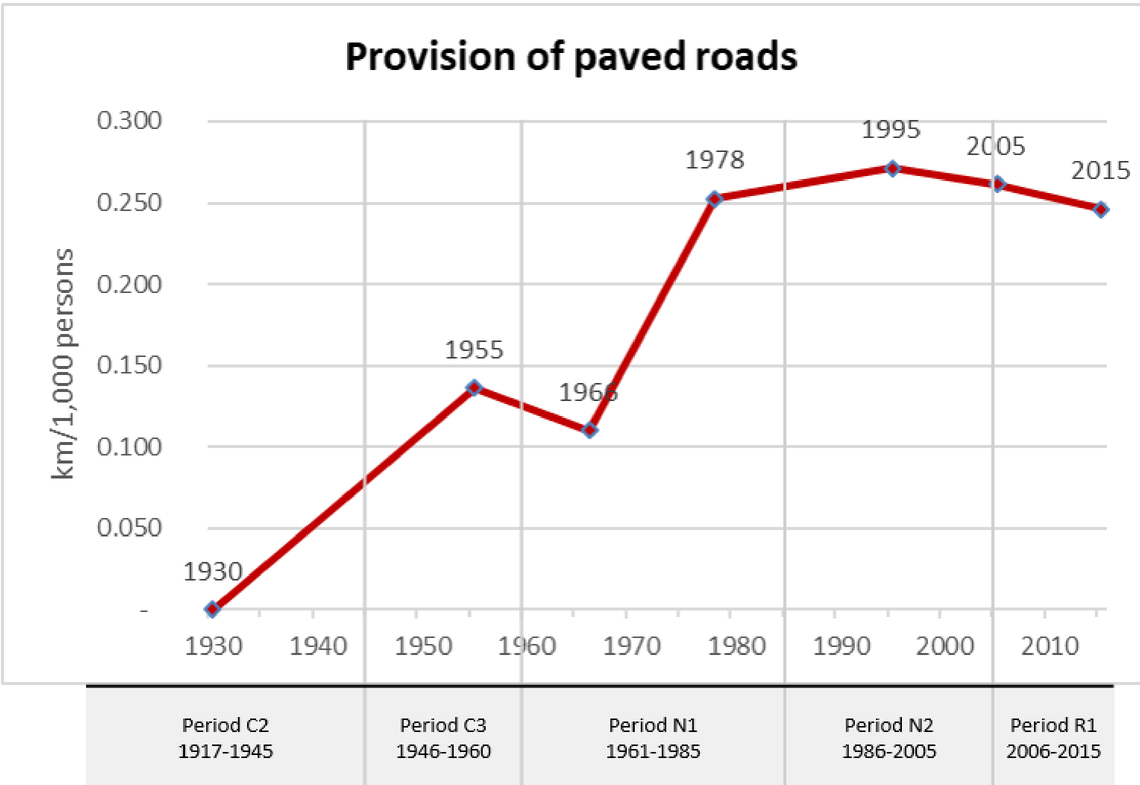


Figure 6.9. Evolution of paved roads per thousand persons in Cameroon (Source: Author)

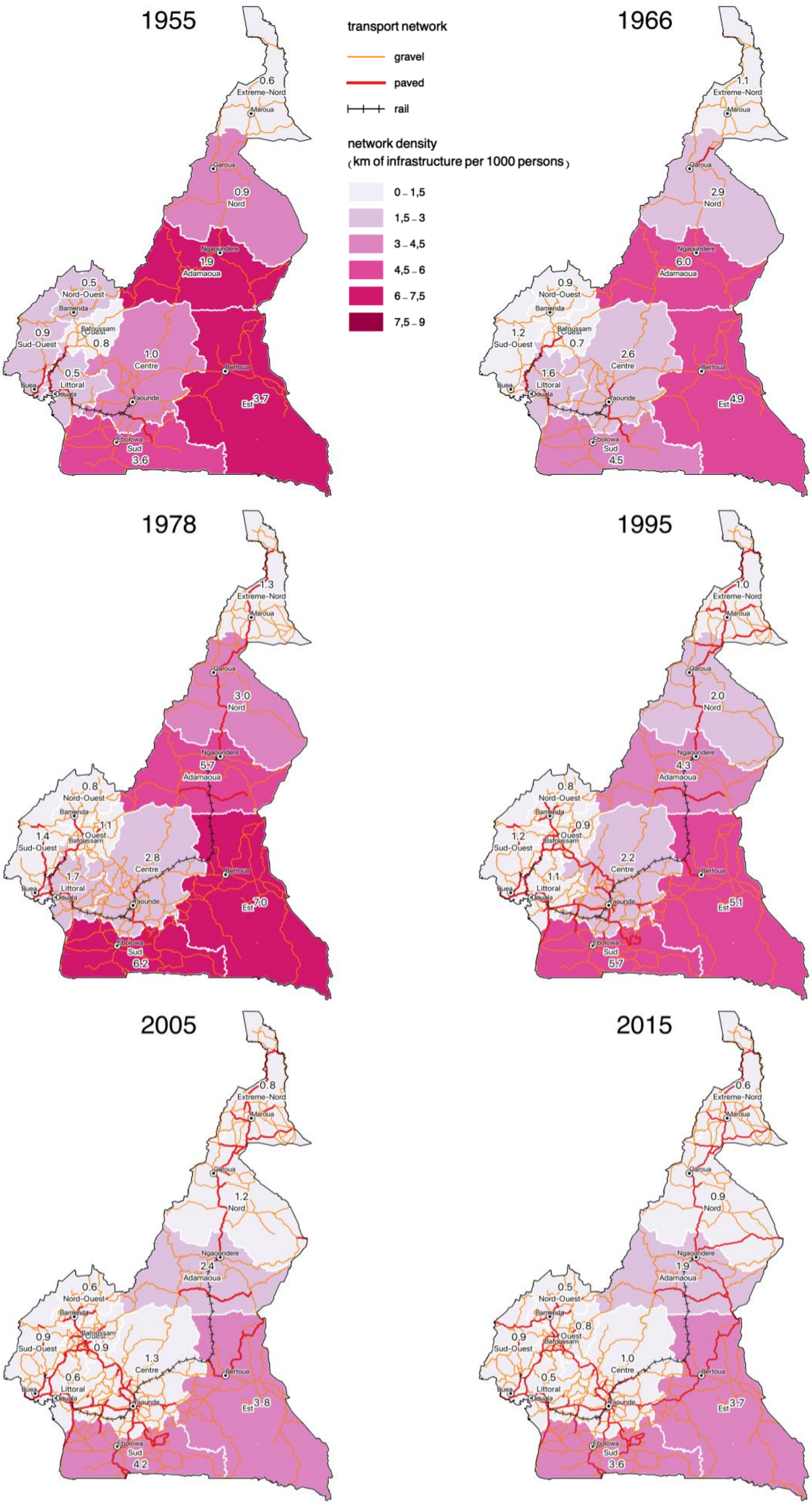


Figure 6.10. Maps showing the evolution of the transport network density per surface of the regions (km of infrastructure per 1000 persons) (Source: Author)

We have calculated the evolution of infrastructure provision per region considering only paved roads. Table 6.5 contains the km of paved roads in each region for every mapped year. These values are represented in the chart on figure 6.11.

	1955	1966	1978	1995	2005	2015
Adamaoua	-	-	314	312	331	612
Centre	92	158	159	766	886	1,037
Est	-	-	-	87	339	566
Extreme-Nord	-	8	288	544	574	568
Littoral	261	200	267	459	497	511
Nord	-	94	343	413	526	666
Nord-Ouest	-	-	29	196	212	277
Ouest	1	71	200	432	417	472
Sud	69	69	69	320	549	616
Sud-Ouest	108	-	267	241	230	406
TOTAL	531	600	1,936	3,770	4,561	5,731

Table 6.5 Paved roads evolution per region (km) (Source: Author)

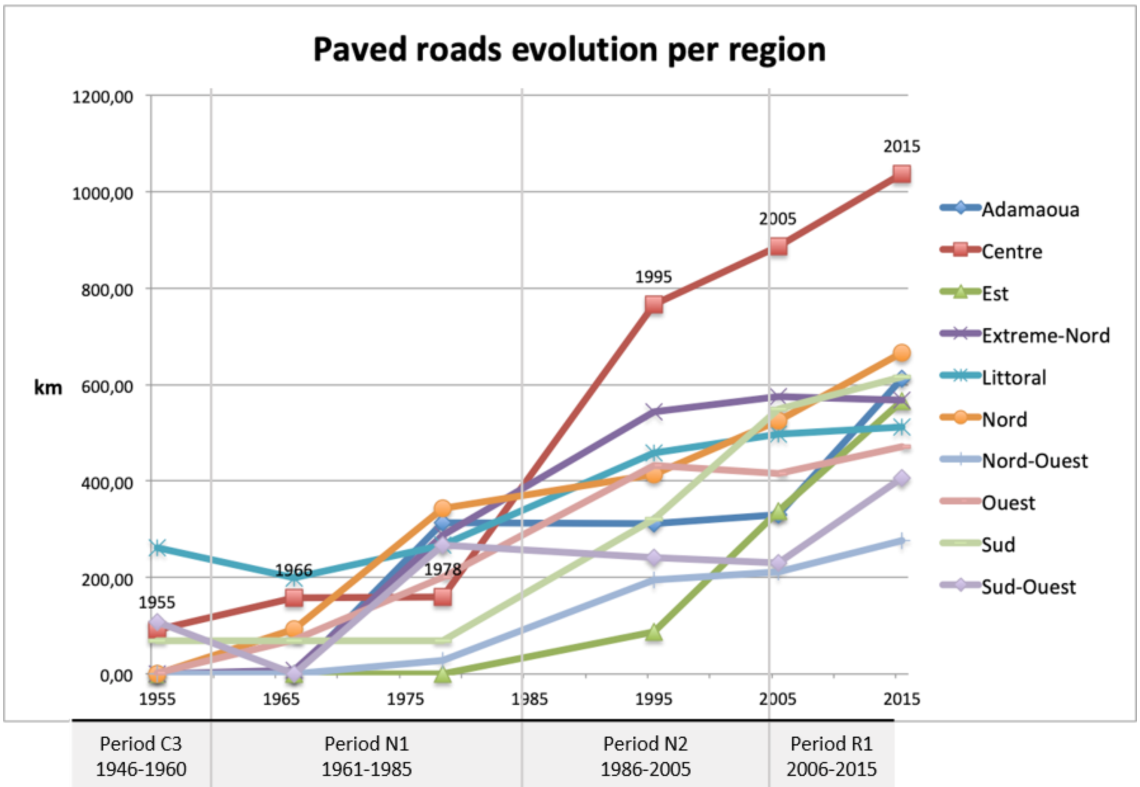


Figure 6.11. Evolution of the paved roads per region (Source: Author)

From 1978, the Centre region is the most favoured one in terms of asphalted roads. It corroborates the findings in the geohistorical section of our research that indicate a concentration of radial transport investments from Yaoundé. At the other end, we find that the Nord-Ouest region is the one with less paved roads. In addition, we observe that the Centre, the Est, the Sud, the Nord and the Adamaoua, have undergone a significant growth of paved roads, while the Extreme-Nord, the Littoral and the Ouest have not experienced any significant progression in the last decades. Naturally, to be able to draw more valid conclusions, we need to look at the provision of paved roads in terms of surface area and population of the regions concerned. This is what we are doing in tables 6.6 and 6.7 and figures 6.12 and 6.13.

	1955	1966	1978	1995	2005	2015
Adamaoua	0.00	0.00	4.99	4.96	5.25	9.71
Centre	1.34	2.32	2.33	11.22	12.99	15.20
Est	0.00	0.00	0.00	0.79	3.09	5.16
Extreme-Nord	0.00	0.23	8.40	15.85	16.72	16.54
Littoral	12.87	9.84	13.16	22.63	24.52	25.21
Nord	0.00	1.41	5.14	6.19	7.87	9.98
Nord-Ouest	0.00	0.00	1.66	11.31	12.28	16.01
Ouest	0.10	5.09	14.30	30.81	29.73	33.68
Sud	1.40	1.40	1.40	6.53	11.19	12.55
Sud-Ouest	4.29	0.00	10.61	9.57	9.14	16.14
TOTAL	1.13	1.28	4.14	8.06	9.75	12.25

Table 6.6 Paved roads density per surface of the region (km of roads per 1000 km2)
(Source: Author)

	1955	1966	1978	1995	2005	2015
Adamaoua	0.00	0.00	0.87	0.63	0.37	0.51
Centre	0.15	0.19	0.14	0.46	0.29	0.25
Est	0.00	0.00	0.00	0.17	0.44	0.68
Extreme-Nord	0.00	0.01	0.21	0.29	0.18	0.14
Littoral	0.73	0.33	0.29	0.34	0.20	0.15
Nord	0.00	0.31	0.72	0.50	0.31	0.27
Nord-Ouest	0.00	0.00	0.03	0.16	0.12	0.14

Ouest	0.00	0.09	0.19	0.32	0.24	0.25
Sud	0.32	0.26	0.22	0.86	0.87	0.82
Sud-Ouest	0.33	0.00	0.43	0.29	0.17	0.26
TOTAL	0.14	0.11	0.25	0.36	0.26	0.26

Table 6.7. Paved roads density per population of the region (km of roads per 1000 persons) (Source: Author)

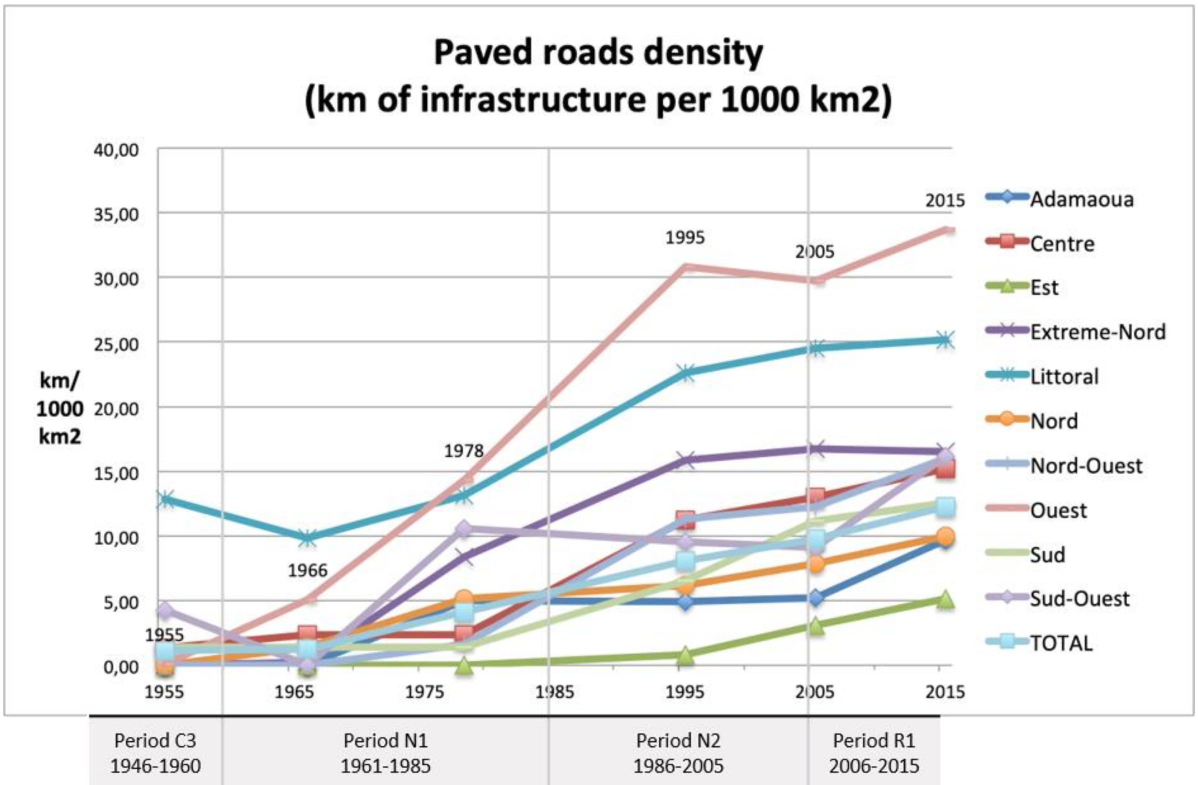


Figure 6.12. Evolution of the paved road density per surface of the regions (Source: Author)

If we look at the length of paved roads in relation to the surface area of the region, we can see that the most favoured region is not the Centre as we have seen in absolute values, but the Ouest, followed by the Littoral. The rest of the regions have similar endowments, and we observe that the Est and Adamaoua, although lagging behind, have caught up in the last decades. In all the regions, even if slow, there is a progression since 1995, except for the Extreme-Nord where the development of the asphalted network stagnates.

However, when we analyse the paved roads provision regarding the population of the regions, the picture changes (figure 6.13). In this case, the Sud, the Est and the Adamaoua regions stand out with the best endowment per person. In addition, the Est and the Adamaoua are the only ones that have experienced an increase in the last decade. For the rest of the regions, the indicator stagnates or even decreases. Contrary to the total provision of transport infrastructure, the fact that paved roads per person declines is not positive as the absolute numbers are very low and we may expect better coverage of paved roads throughout the country.

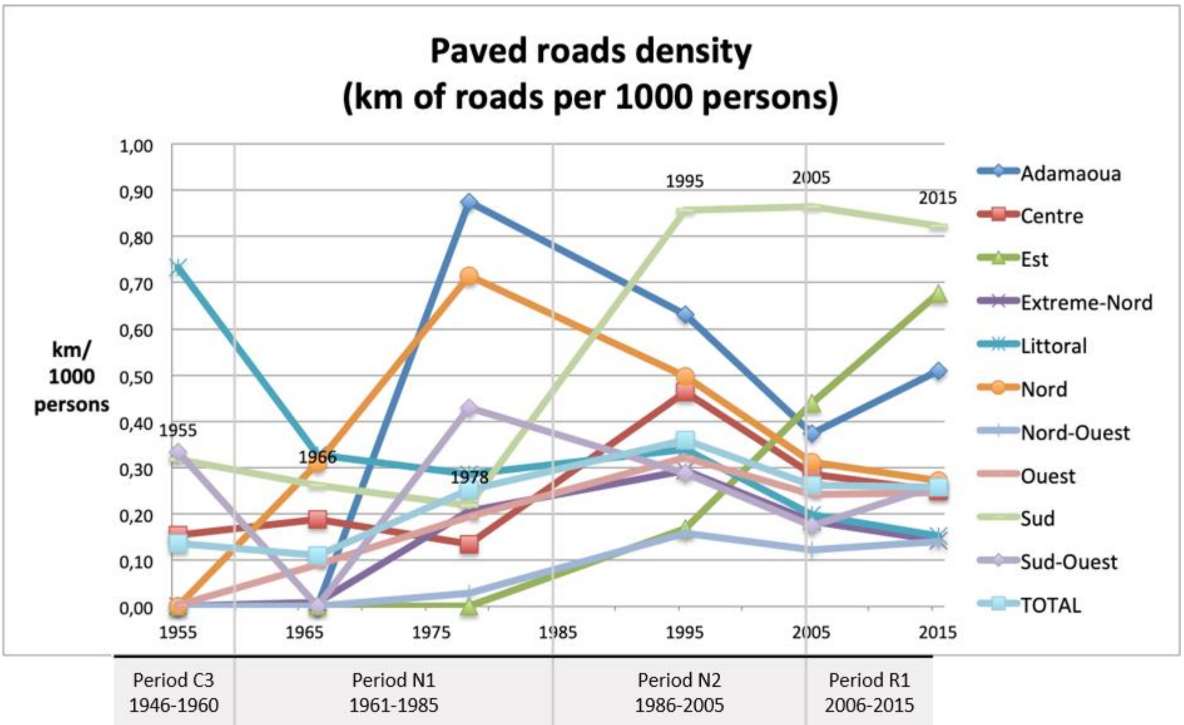


Figure 6.13. Evolution of the paved road density per population of the regions (Source: Author)

Looking at the above graphs and tables, we can summarise the findings as follows:

- While the Centre region, where the capital Yaoundé is located, has the longest transport (and paved) network, it is the Ouest, the smallest region, the one with denser infrastructure per km^2, followed by the Littoral.

- Despite the "outliers", when looking at transport infrastructure density (and paved roads) per surface area, we appreciate a certain convergence between regions, which may show the willingness of the Government to ensure equality between regions. It also happens when looking at paved roads only.

- The lower the population, the highest the network endowment is. This would indicate a policy aimed at ensuring the presence of the state throughout the territory and address inequalities, even if those investments are in large and low populated areas and while they would be more needed in other regions.

- When looking at the overall transport infrastructure provision in relation to the population, it declines in all the regions as population grows. However, the density of paved roads shows a disparate situation, growing in certain regions while declining or stagnating in others, depending on the period. We interpret these varying situations as the inability of the Government to improve the asphalted network simultaneously in different regions.

6.2.2. Fractal index

In the previous section, we examined separately the network density indices for surface area and population. Although it can be preliminarily concluded that transport policies in Cameroon tend to favour a homogeneous distribution between regions according to population and surface area, these indices do not help us to determine the optimal provision of transport networks in each region in relation to the country as a whole.

In Cameroon, territorial policies have been markedly fractal. In 1961, the Federal Republic of Cameroon created five administrative regions in the former French Cameroon: the North, the East, the Centre-South, the Littoral and the West. The constitutional revision of 2 June 1972 renamed them as provinces and divided West Cameroon (former British Cameroon) into North-West and South-West[96]. On 22 August 1983, the number of provinces was increased to 10, following the division of the North into three new provinces (North, Far-North and Adamaoua), and the Centre-South into two (the Centre and the South). From 2008, Cameroon's provinces have been called regions. These successive divisions from six to ten regions reinforced the initial choice of the French colony that tried to evenly distribute the population across the regions, that is, delineating smaller regions where there is higher population density and larger regions in zones with scattered populations.

This attempt of making the regions more equal can be observed by comparing the proportion of surface area of each region in relation to the entire country with the population distribution per region in 1976 (figures 6.14 and 6.15). This was some years before the most recent partitioning, but as we have explained, we have estimated the population distribution as if the currently divisions already existed. We note that, while the surface area difference between the smallest region (the Ouest) and the largest one (the Est) is very important, in terms of population, we observe a more equal distribution.

Figure 6.16 shows the population density at regional level in 1976 and transport network in 1978 and we can observe how the smallest regions have the highest densities (mapped with darkest green).

[96] The official English names are North-West and South-West but in this part of the research we will use the French denomination

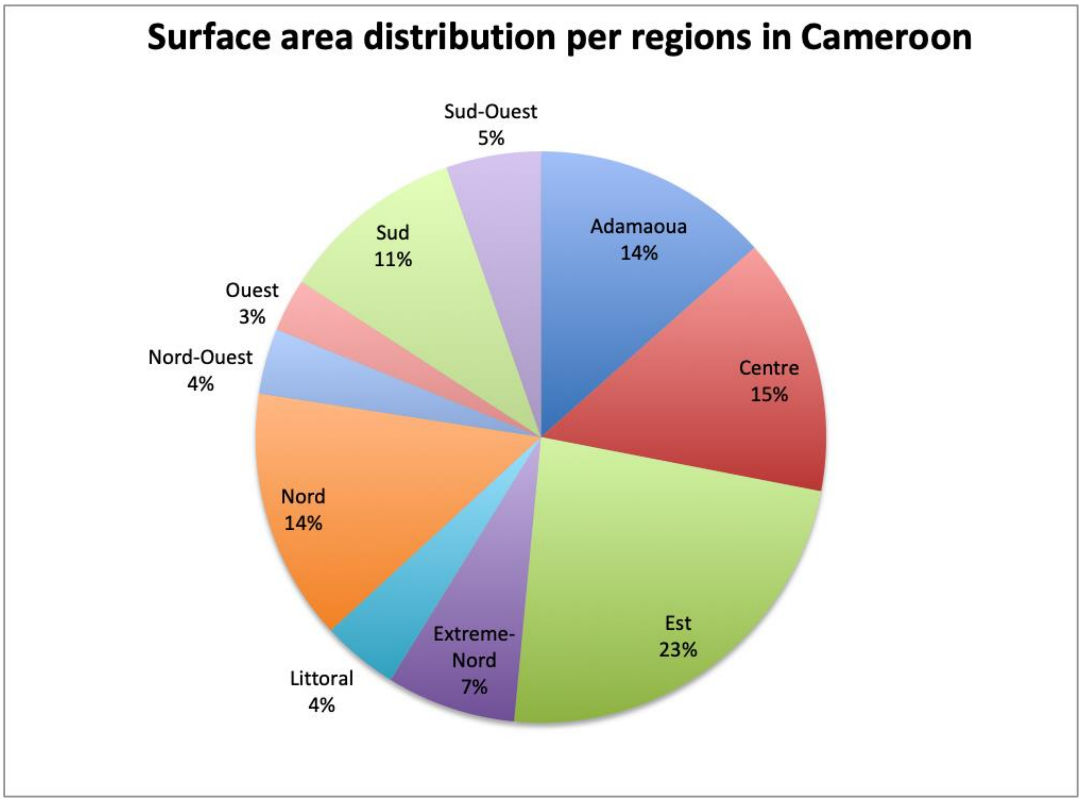


Figure 6.14. Surface area distribution of the regions in relation to the entire country (Source: Author)

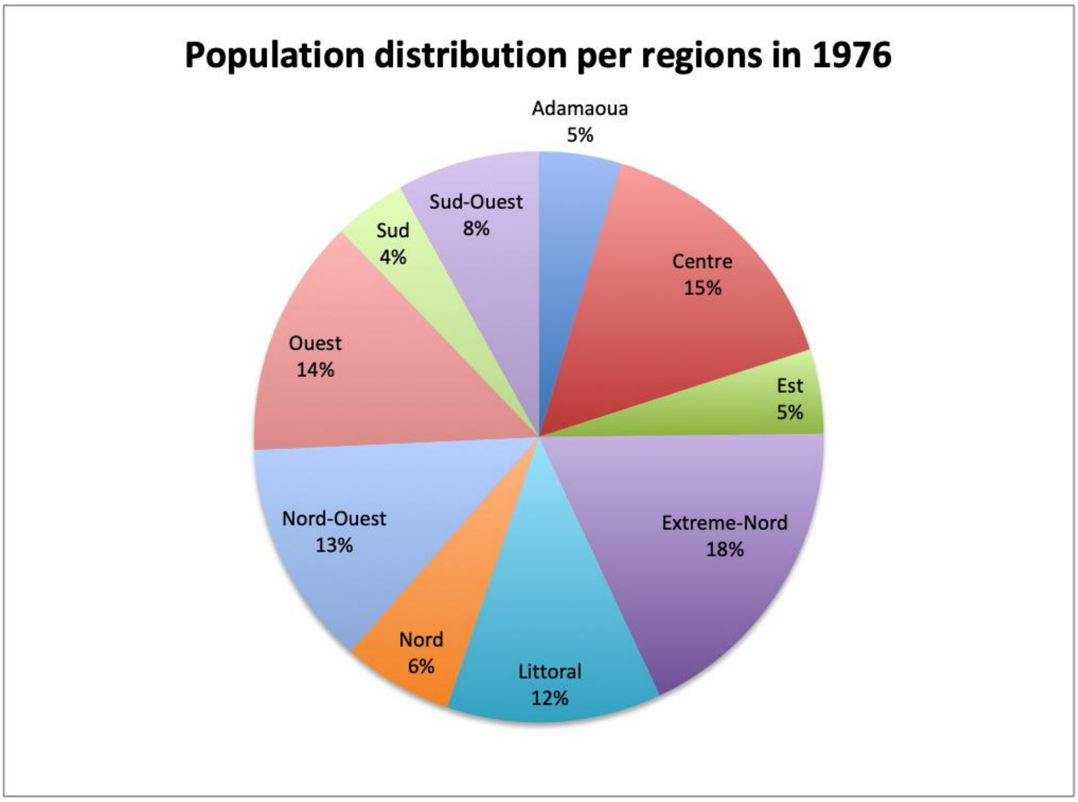


Figure 6.15. Population distribution per regions in 1976 (Source: Author based on public statistics)

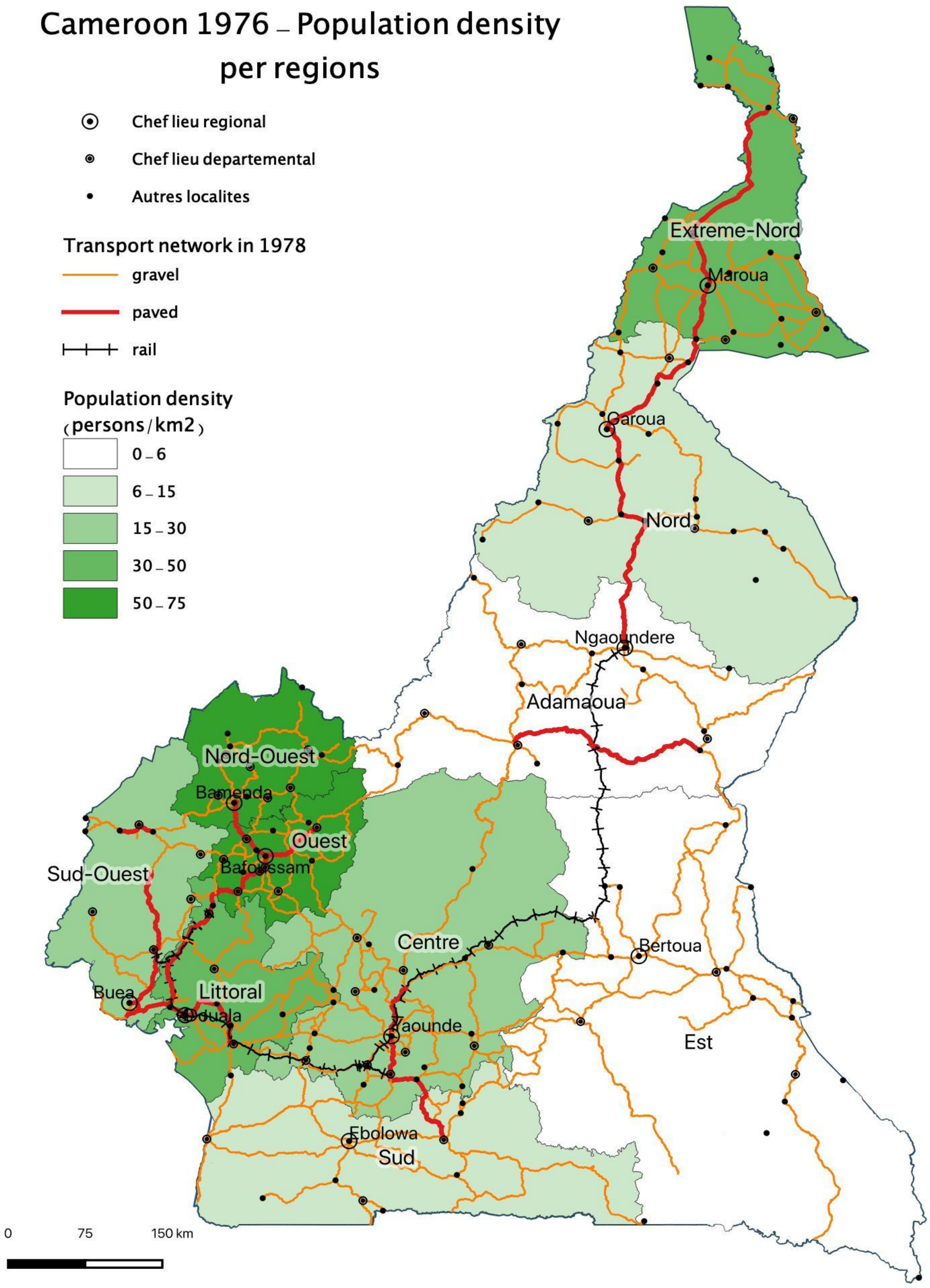


Figure 6.16. Population density at regional level in 1976 and transport network in 1978
(Source: Author)

Since the zones with more population were originally the ones with more transport infrastructure, this breaking up into smaller regions has favoured a fractal model. This fractality is also observed at department level, since the densest and smallest regions like the Ouest and the Nord-Ouest have also been divided into a larger number of departments. In table 6.8, we have listed in decreasing order the existing densities per region in 1976 and compared it to the number of departments per region. Apart from the Littoral and the Centre, the densest regions have been divided into more departments than the others (see also figure 6.2).

	Population density in 1976	Number of departments
Ouest	73.90	8
Nord-Ouest	56.66	7
Littoral	46.10	4
Extreme-Nord	40.62	6
Sud-Ouest	24.69	6
Centre	17.25	10
Nord	7.18	4
Sud	6.42	4
Adamaoua	5.71	5
Est	3.34	4

Table 6.8 Population density in 1976 (persons/km2) and number of departments per region (Source: Author)

In the case of the Littoral, the population is essentially concentrated in the Wouri, and further partition according to a fractal logic would have implied to split the capital Douala into different departments. The political reasons behind the "overpartition" of the Centre have not been studied in this research. However, interestingly, we observe that the division into departments also obeys to a fractal vision, with the most populated departments (Mfoundi/Yaoundé and Lekié) being also the smallest, and the largest department (Mbam-et-Kim), occupying 37.5% of the region, being barely populated (table 6.9 and figure 6.17).

Department	Surface (km2)	Population in 1976	Density in 1976 (persons/km2)
Haute-Sanaga	10,967.30	56,189	5.12
Lekie	3,119.89	203,159	65.12
Mbam et Inoubou	6,670.57	127,683	19.14

Mbam et Kim	27,429.60	36,738	1.34
Mefou et Afamba	3,333.58	74,083	22.22
Mefou et Akono	1,322.22	50,284	38.03
Mfoundi (Yaoundé)	290.12	313,206	1079.56
Nyong et Kelie	5,291.66	86,668	16.38
Nyong et Mfoumou	6,166.04	72,865	11.82
Nyong et So'o	3,631.17	77,805	21.43

Table 6.9 Characteristics of surface and population of the Centre region in 1976 (Source: Author)

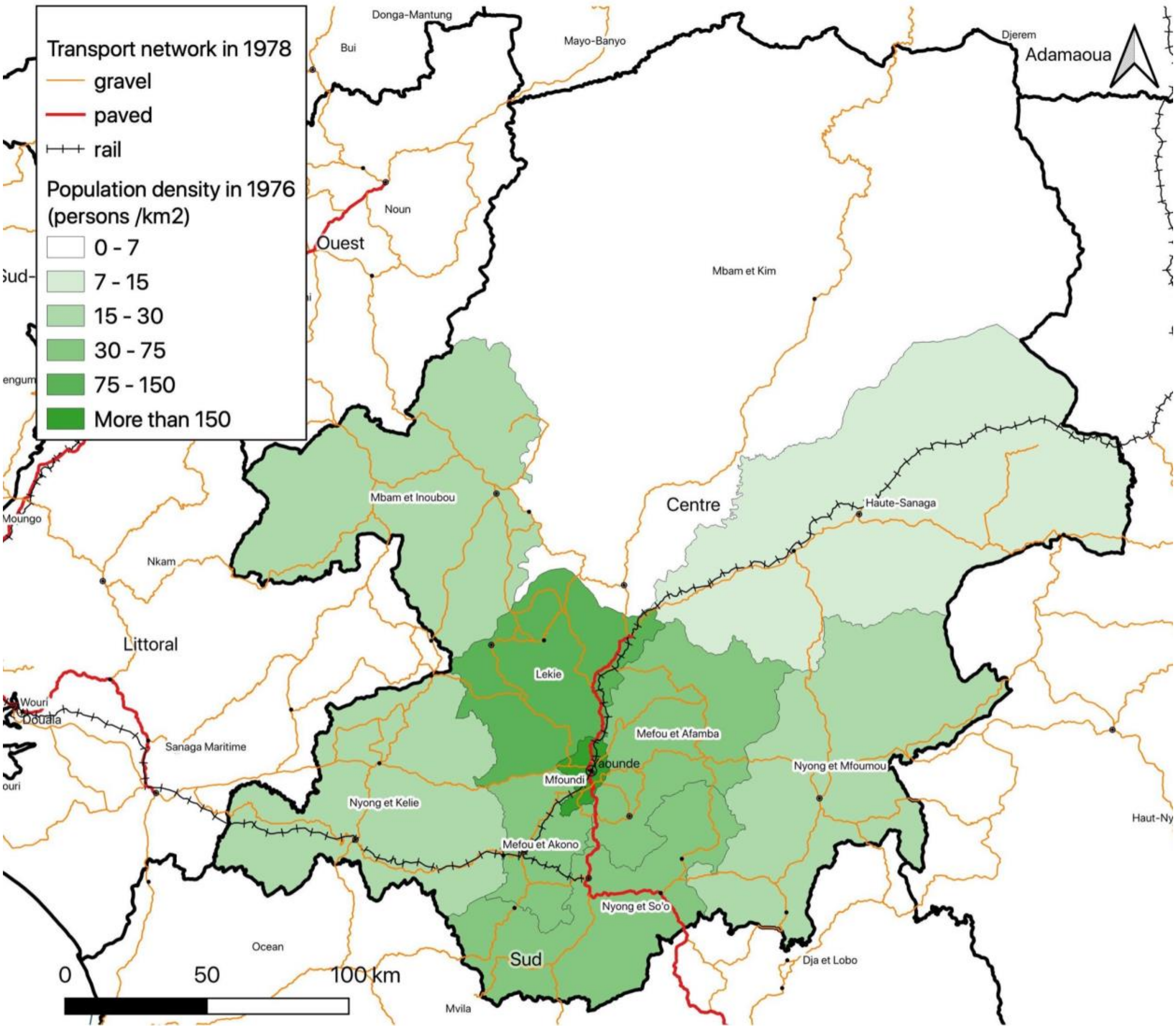


Figure 6.17. Densities per department in the Centre region in 1976 (Source: Author)

The question to be asked is whether, in addition to these regional partitions, transport policies have also favoured the territorial balance sought by the authorities. The fractal index F can be used to provide an answer. In the case of Cameroon, we can calculate, for each of the studied years, the weights p and s by maximising the R-squared value (the square of the Pearson correlation coefficient) obtained when running simple linear regressions between the independent variable $P^p \ x \ S^s$ and the dependent variable L. To calculate this maximum, the weights of p and s are varied until an approximation of the vertex of the parabola is obtained. We provide here the calculations for 2015 using as territorial units, first, the regions (figure 6.18) and then, the departments (figure 6.19). The regression equation and the R-squared values are calculated using the statistics software R.

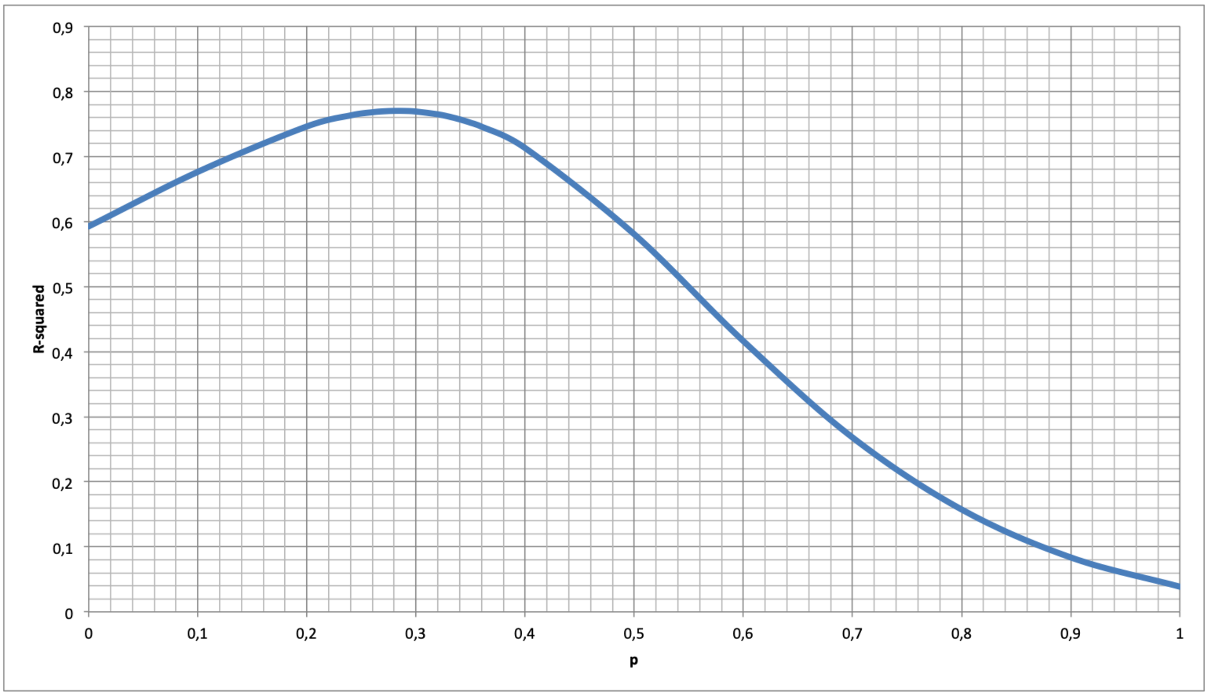


Figure 6.18. R-squared coefficients for different values of the weight 'p' assigned to the population per regions in 2015 (Source: Author)

In 2015, a p weight of 0.28 maximises the R-squared providing a value of 0.770. The best fitting linear regression equation for regions in 2015 is:

*Length = 473.7728 + 0,66158*Population^0.28*Surface^0.72*

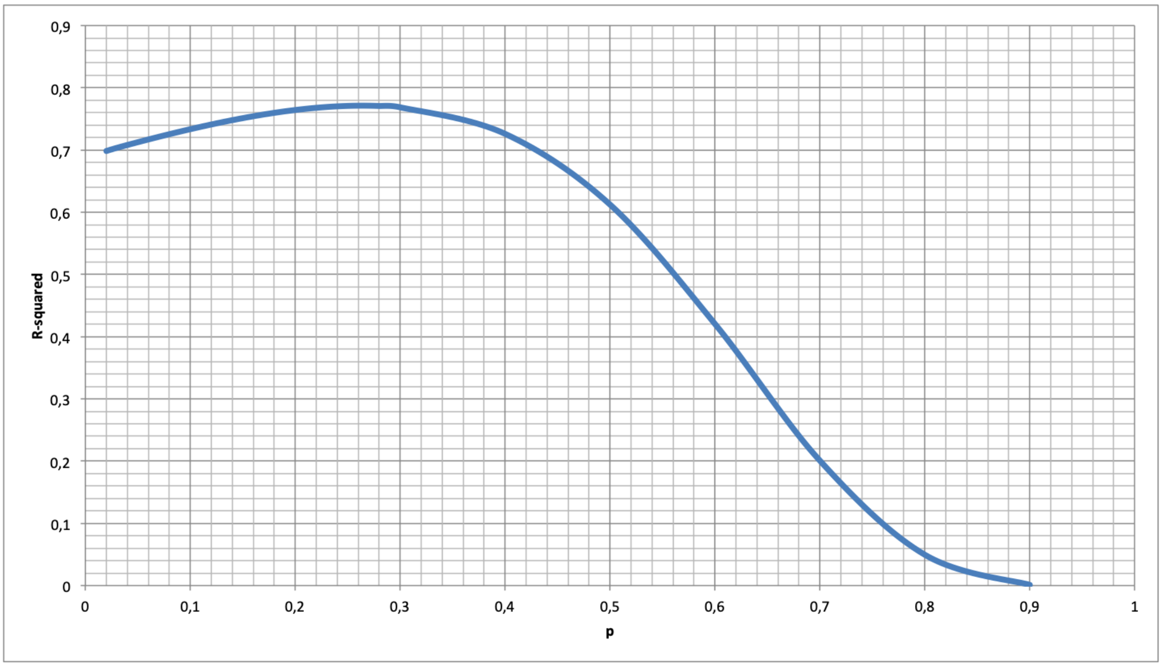


Figure 6.19. R-squared coefficients for different values of the weight 'p' assigned to the population per departments in 2015 (Source: Author)

In 2015, a *p* weight of 0.26 maximises the R-squared providing a value of 0.771. The best fitting linear regression equation for departments in 2015 is:

*Length = 96.17312 + 0.56982*Population^0.26*Surface^0.74*

Larrosa's thesis concerning the fractality of the F-index is confirmed by the fact that the weights *p* and *s* are approximately the same both at departmental and regional level. Therefore, for simplicity, for the rest of the years of study, we have calculated the weights *p* and *s* only at regional level. Table 6.10 contains the values of F for the studied years in each of the regions, as well as, in the first row, the *p* and *s* weights obtained from the linear regression maximising the R-squared values. We provide the F index for the entire country in the row called Cameroon. These country level values are not the mean or the addition of the indices for the regions taken separately but result from applying the formula to the total length of the transport network, total population and total surface area of Cameroon. The row 'F-deviation' expresses the average distance between the F index of each of the regions and the F index of the entire country. 'Regions below F' is the number of regions for each studied year that have an F index below the one for the entire country.

	1955	1966	1978	1995	2005	2015
	P^0.37 S^0.63*	*P^0.41* S^0.59*	*P^0.37* S^0.63*	*P^0.35* S^0.65*	*P^0.34* S^0.66*	*P^0.28* S^0.72*
Adamaoua	2.32	3.56	2.83	2.04	1.49	0.75
Centre	2.30	3.34	2.83	2.16	1.75	0.89
Est	1.63	2.42	2.50	1.77	1.52	0.77
Extreme-Nord	1.38	2.22	2.28	1.72	1.61	0.86
Littoral	2.53	3.42	3.14	2.03	1.50	0.85
Nord	1.23	2.02	1.74	1.33	1.15	0.59
Nord-Ouest	1.90	2.40	1.74	1.62	1.37	0.77
Ouest	1.68	2.25	2.81	2.14	2.26	1.27
Sud	2.31	3.49	3.34	2.67	2.49	1.22
Sud-Ouest	1.48	2.03	1.78	1.49	1.38	0.88
Cameroon	**1.67**	**2.42**	**2.23**	**1.69**	**1.46**	**0.77**
F-deviation	0.40	0.53	0.55	0.33	0.29	0.16
Regions below F	3	4	3	2	1	1

Table 6.10. F index and weights 'p' and 's' by regions for the total transport network in selected years (Source: Author)

The weight *p* assigned to the population increased from 0.37 in 1955 to 0.41 on 1966, and then has declined over the studied years, from 0.37 to 0.28 (figure 6.20). It means that, from independence, transport policies in Cameroon have favoured spatial coverage in all the regions to the detriment of areas where most of the population is located, and that this trend has been reinforced over the years. At the same time, as these transport policies are based on a spatial homogenization of the network, they have facilitated a more equal distribution of transport infrastructure between regions.

In table 6.10 we observe that, from the 1950s to the 1970s, 3-4 regions were lagging behind, with F values below the index at country level; nowadays, there is only one backward region, the Nord. This uniformising trend can also be observed in figure 6.21 where we have graphed the values of table 6.10 with radar charts. While, until the 1970s, the charts have a star shape, with some noticeable peaks, in the last decades, the shapes have been rounding off.

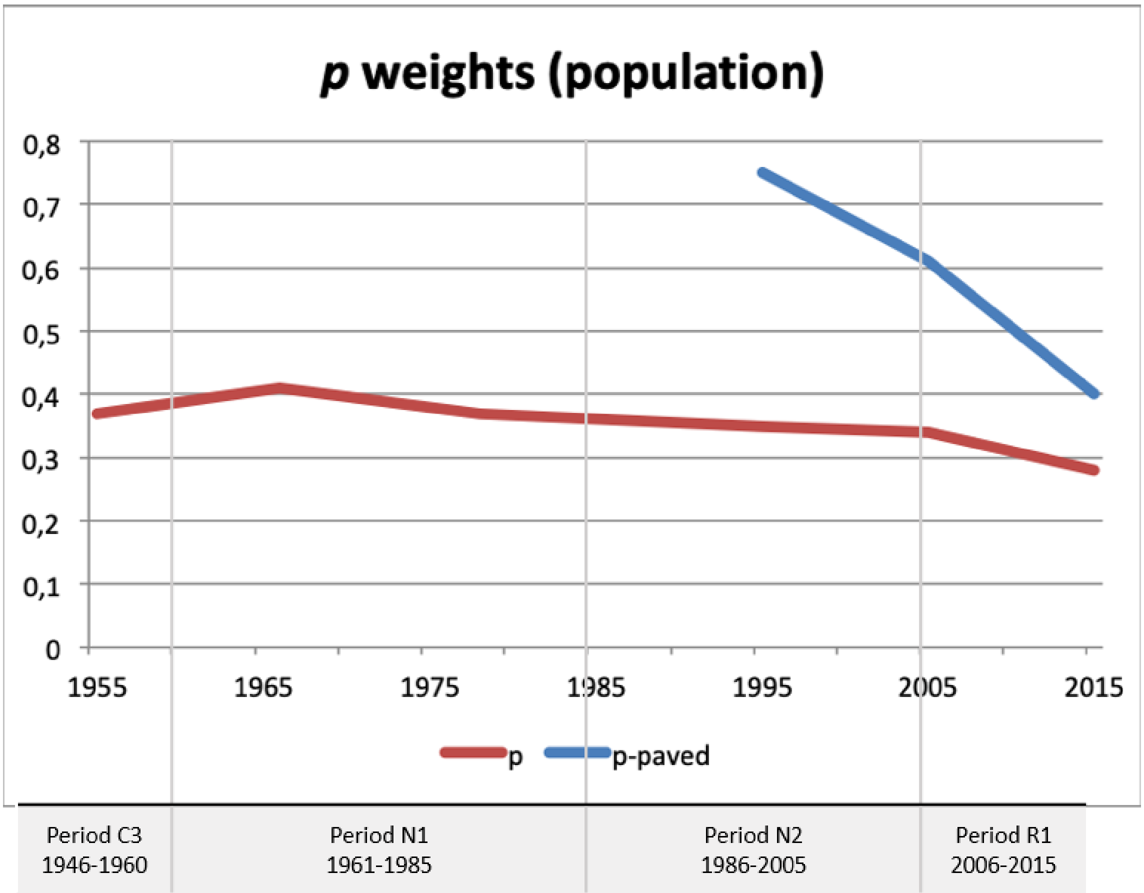
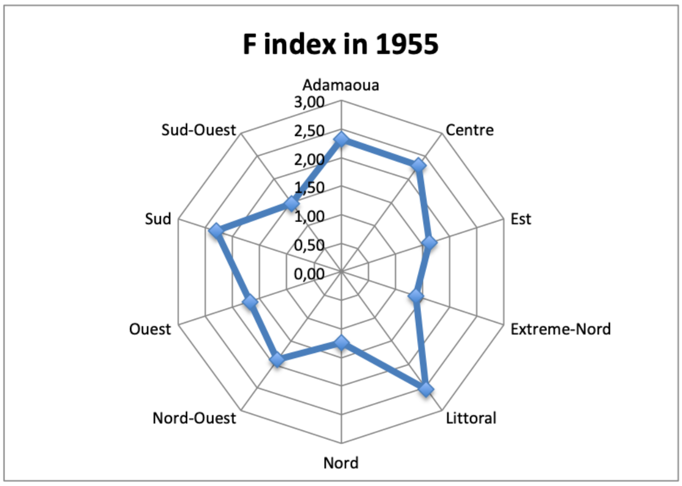
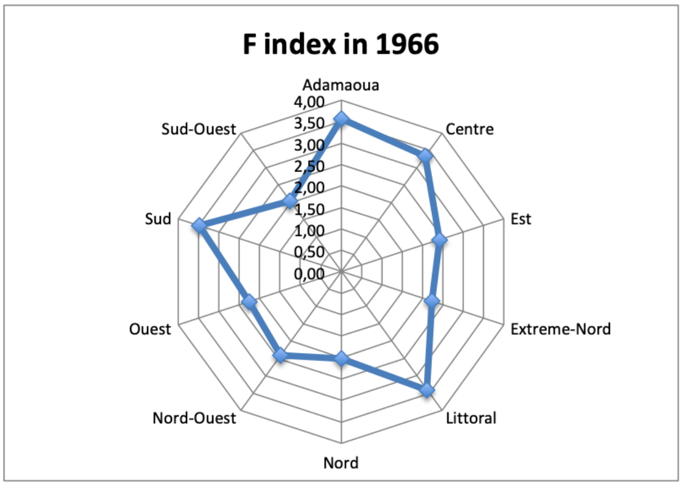


Figure 6.20. Evolution of the weights assigned to the population when calculating the F index for the total network (p) and for the paved network (p-paved) (Source: Author)





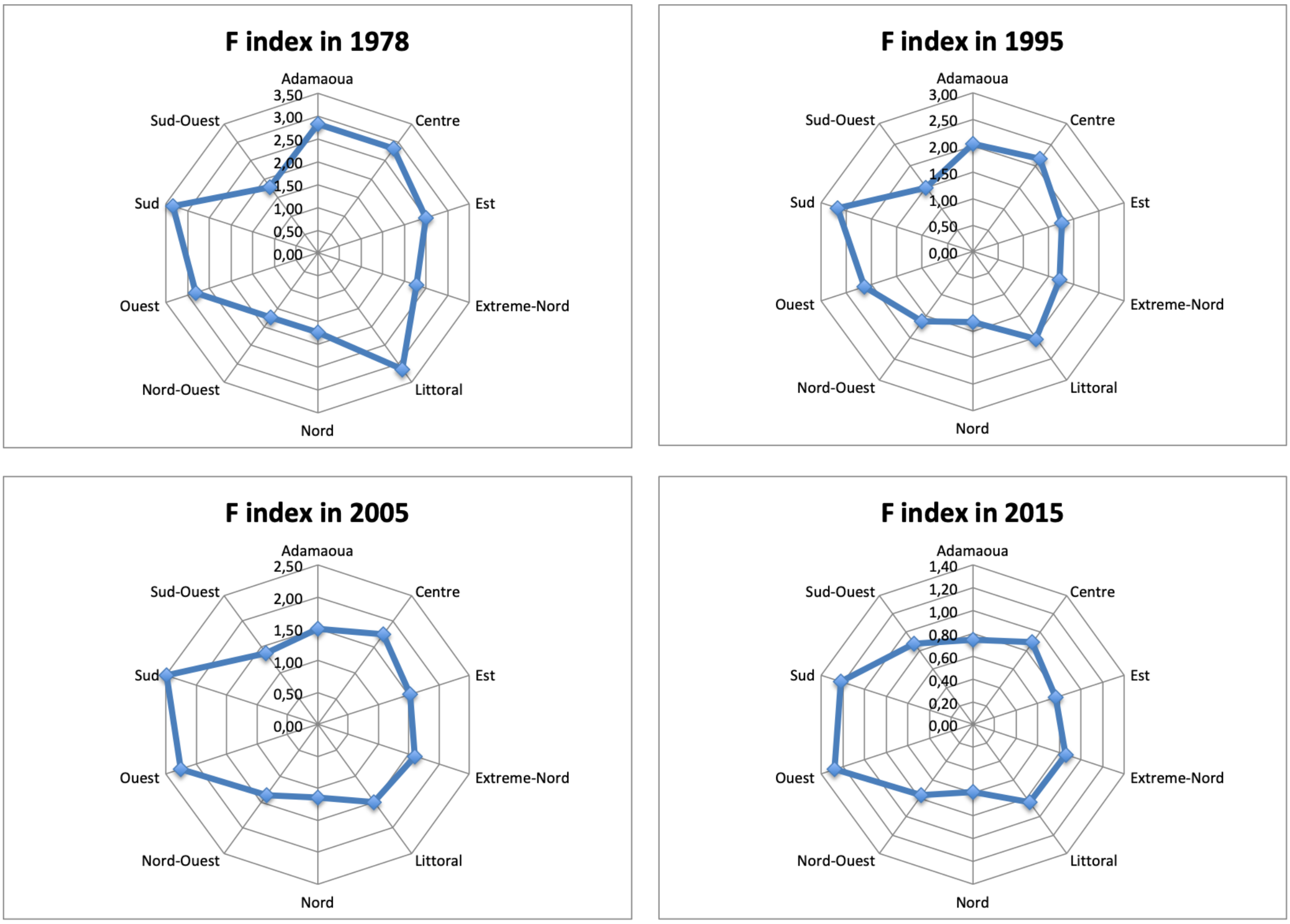


Figure 6.21. Radial charts of F index by regions in successive years (Source: Author)

In table 6.11 and figure 6.22, we have represented the ranking of the regions according to the best F values obtained in the studied years. We note that the Sud and the Centre are, over the years, well endowed, while the Nord has been regularly the region obtaining the worst F values. The Nord-Ouest is also a region that appears systemically in the last positions of the ranking. Also remarkable is the fall of the Adamaoua region from the first place in 1966 to the second to last in 2015. Other regions experiencing a significant drop are the Littoral, which passed from the top position in 1955 to the sixth in 2015. In the opposite direction, we found the Ouest, from the seventh position in 1966 to the first one in 2015, the Sud-Ouest from ninth in 1966 to fourth in 2015 and, finally, the Extreme-Nord, which went from the ninth position in 1955 to the fifth in 2015.

1955	*1966*	*1978*	*1995*	*2005*	*2015*
*P^0.37**	*P^0.41**	*P^0.37**	*P^0.35**	*P^0.34**	*P^0.28**
S^0.63	*S^0.59*	*S^0.63*	*S^0.65*	*S^0.66*	*S^0.72*

1	*Littoral*	*Adamaoua*	*Sud*	*Sud*	*Sud*	*Ouest*
2	*Adamaoua*	*Sud*	*Littoral*	*Centre*	*Ouest*	*Sud*
3	*Sud*	*Littoral*	*Adamaoua*	*Ouest*	*Centre*	*Centre*
4	*Centre*	*Centre*	*Centre*	*Adamaoua*	*Extreme-Nord*	*Sud-Ouest*
5	*Nord-Ouest*	*Est*	*Ouest*	*Littoral*	*Est*	*Extreme-Nord*
6	*Ouest*	*Nord-Ouest*	*Est*	*Est*	*Littoral*	*Littoral*
7	*Est*	*Ouest*	*Extreme-Nord*	*Extreme-Nord*	*Adamaoua*	*Nord-Ouest*
8	*Sud-Ouest*	*Extreme-Nord*	*Sud-Ouest*	*Nord-Ouest*	*Sud-Ouest*	*Est*
9	*Extreme-Nord*	*Sud-Ouest*	*Nord*	*Sud-Ouest*	*Nord-Ouest*	*Adamaoua*
10	*Nord*	*Nord*	*Nord-Ouest*	*Nord*	*Nord*	*Nord*

Table 6.11. Region rankings according to F index in studied years (Source: Author)

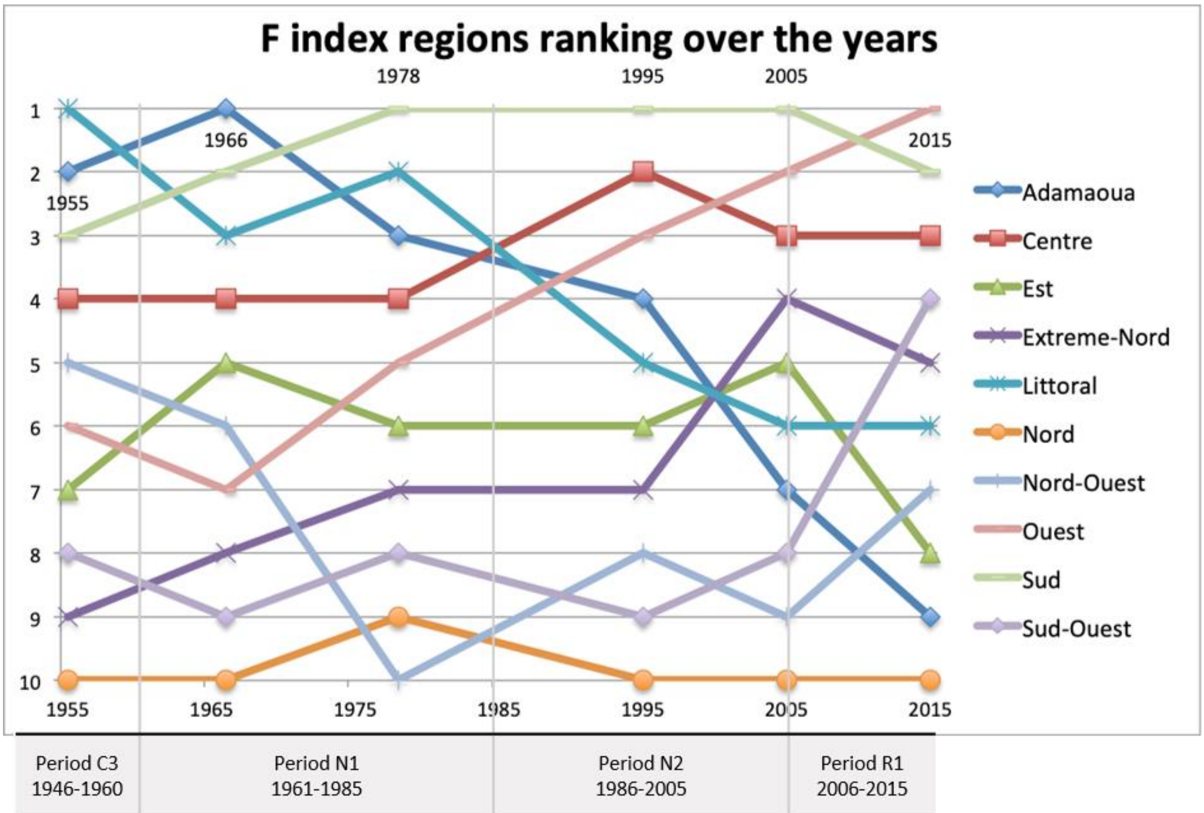


Figure 6.22. Evolution of the region rankings according to F values in studied years
(Source: Author)

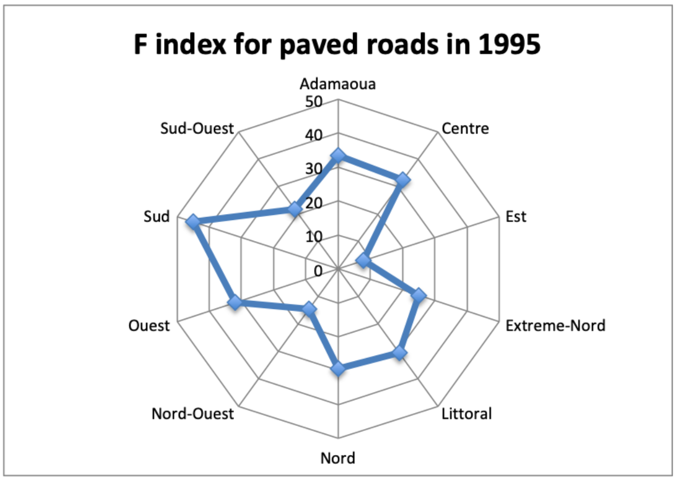
From these rankings based on the F value, it is important to retain the tendency of the Sud, the Ouest and the Centre regions to be better endowed, while the Nord, the Adamaoua and the Est regions have had over the years a worse infrastructure provision. The good situation of the Sud region in relation to other comparable regions in terms of surface area and population, such as the Est, the Nord and the Adamaoua, has been established thanks to the F index. Classical indicators of infrastructure density are not able to establish these distinctions as clearly.

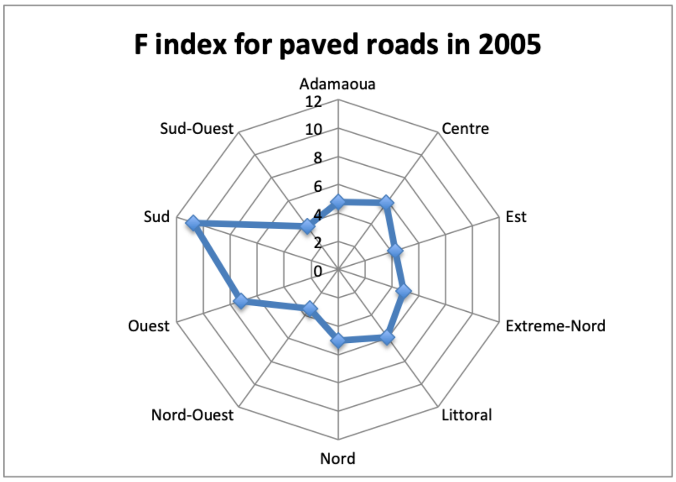
In table 6.12, we have recorded the values of F in each of the regions calculating them only for the paved road network. In this case, we can only estimate the weights and the F-index from 1995. In the previous years, there were regions with zero kilometres of paved roads, making it impossible to calculate correlations. As we can observe, while initially the weight given to the population in the development of paved roads was very high, 0.75 in 1995, the value dropped sharply in just ten years, 0.4 in 2015 (see also figure 6.20).

	1995	**2005**	**2015**
	*P^0.75*S^0.25*	*P^0.61*S^0.39*	*P^0.4*S^0.6*
Adamaoua	33.38	4.79	0.75
Centre	32.52	5.79	0.74
Est	7.84	4.29	0.57
Extreme-Nord	25.14	4.89	0.62
Littoral	30.67	5.93	0.82
Nord	29.51	5.02	0.59
Nord-Ouest	14.55	3.38	0.61
Ouest	31.87	7.23	1.18
Sud	45.03	10.73	1.06
Sud-Ouest	21.81	3.74	0.78
Cameroon	**24.72**	**4.90**	**0.66**
F-deviation	8.50	1.36	0.16

Table 6.12. F index and weights 'p' and 's' by regions for the paved road network in selected years (Source: Author)

According to the weights obtained, when we look only at the asphalt network, we conclude that it was originally prioritised where there was more population and then this option was progressively abandoned. This change in road development policies corresponds to the geohistorical review that we have conducted in chapter 4. Initially, from the 1940s onwards, when confronted with the enormous challenge of overlying the entire network with limited budgets, the most obvious choice was to start with the sections close to the cities. As the network becomes more asphalted, other territorial considerations take over. The spatial homogenization observed for the total network occurs also for the paved roads. We can observe this evolution in the radial charts in figure 6.23, where the representation passes from a star shape to an oval one. Like for the total network, the Sud and the Ouest appear as the best endowed regions.





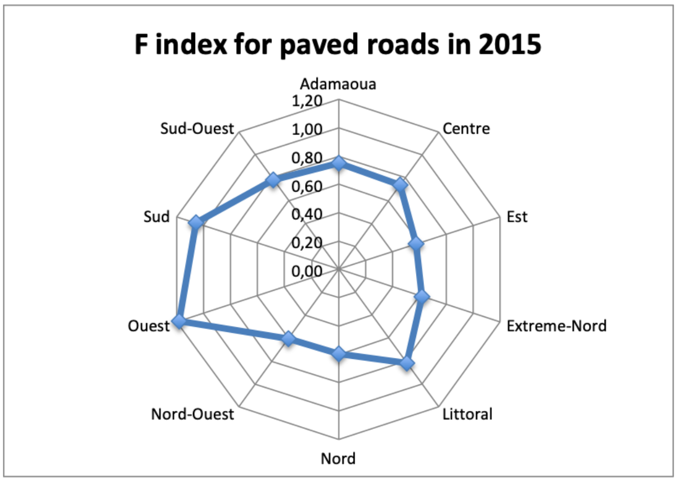


Figure 6.23. Radial charts of F index for the paved roads by regions in successive years
(Source: Author)

In conclusion, the F-index has properties that allow us to confirm quantitatively the outcome of certain transport policies that we had previously identified. While initially there is a tendency to concentrate the investments on the most populated areas, where there are more immediate benefits, later, as the country develops, the development of the network responds to other criteria. The need to cover the country spatially and connect less populated areas prevails, even if the projects have lower economic returns. This choice allows for more territorial equality but not necessarily an optimisation of resources to obtain a more efficient network.

6.2.3. Poverty and transport infrastructure

We complete the territorial and demographic analysis looking at the evolution of the socio-economic indicators in the different regions and putting it in relation to the transport network. In Cameroon, the historical series of development indicators characterising the socio-economic situation of the population by regions are relatively recent. The first exercise to gather such data started in 1996[97] with the publication of the first Cameroonian Household Survey, better known by its French acronym ECAM (*Enquête Camerounaise Auprès des Ménages*). Since then, three more surveys have been published containing data from 2001[98], 2007[99] and 2014[100]. The information on the characteristics of the population obtained from older reports, for example, in the *Plans quinquennaux,* is of different nature and cannot be exploited along with the more recent statistics.

Table 6.13 and figure 6.24 respectively compile and represent the poverty rates by regions determined in the four ECAMs. These rates reflect the incidence of poverty as the proportion of individuals below the poverty line. The ECAM reports calculate these rates according to the methodology proposed by Foster, Greer & Thorbecke (1984). The first ECAM in 1996 did not use the current administrative partition consisting of ten regions. Poverty rates were provided by agro-ecological regions (savannah, forest, grassfields), plus Douala and Yaoundé. It is certainly not accurate but, for illustrative purposes, the data from 1996 is used by assuming that savannah corresponds to the Adamaoua, Nord and Extreme-Nord regions, forest to the Centre, Est and Sud and grassfields to the Ouest, Nord-Ouest and Sud-Ouest.

	1996	2001	2007	2014
Douala	37.3%	10.9%	5.5%	4.2%
Yaoundé	49.0%	13.3%	5.9%	5.4%
Adamaoua	44.4%	48.4%	55.0%	47.1%
Centre (excluding Yaoundé)	72.5%	48.2%	41.2%	30.3%
Est	72.5%	44.0%	50.4%	30.0%

[97] Direction de la Statistique et de la Comptabilité Nationale (1997), Conditions de vie des ménages au Cameroun en 1996, Résultats de l'ECAM I, Yaoundé.

[98] Direction de la Statistique et de la Comptabilité Nationale (2002), Conditions de vie des populations et profil de pauvreté au Cameroun en 2001, Rapport principal de l'ECAM II, Yaoundé.

[99] Institut National de la Statistique (2007). Troisième Enquête Camerounaise Auprès des Ménages (ECAM-III), Yaoundé.

[100] Institut National de la Statistique (2014). Quatrième Enquête Camerounaise Auprès des Ménages (ECAM-IV), Yaoundé.

Extreme-Nord	44.4%	56.3%	65.9%	74.3%
Littoral (excluding Douala)	72.5%	35.5%	30.8%	19.5%
Nord	44.4%	50.1%	63.7%	67.9%
Nord-Ouest	62.9%	52.5%	51.0%	55.3%
Ouest	62.9%	40.3%	28.9%	21.7%
Sud	72.5%	31.5%	29.3%	34.1%
Sud-Ouest	62.9%	33.8%	27.5%	18.2%
TOTAL	53.3%	40.2%	39.9%	37.5%

Table 6.13. Poverty rates in Cameroon by regions (Source: ECAM I, II, II and IV)

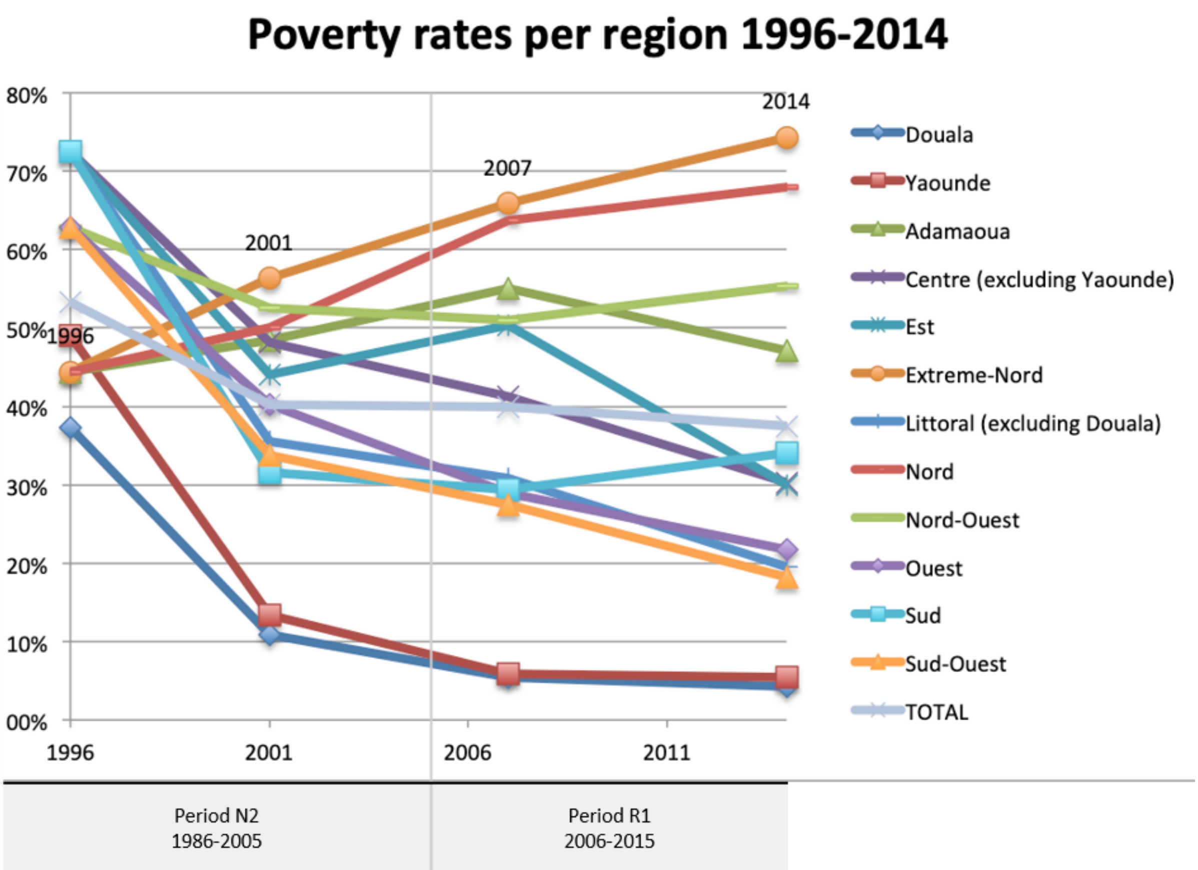


Figure 6.24. Evolution of the poverty rates in Cameroon by regions (Source: ECAM I, II, II and IV)

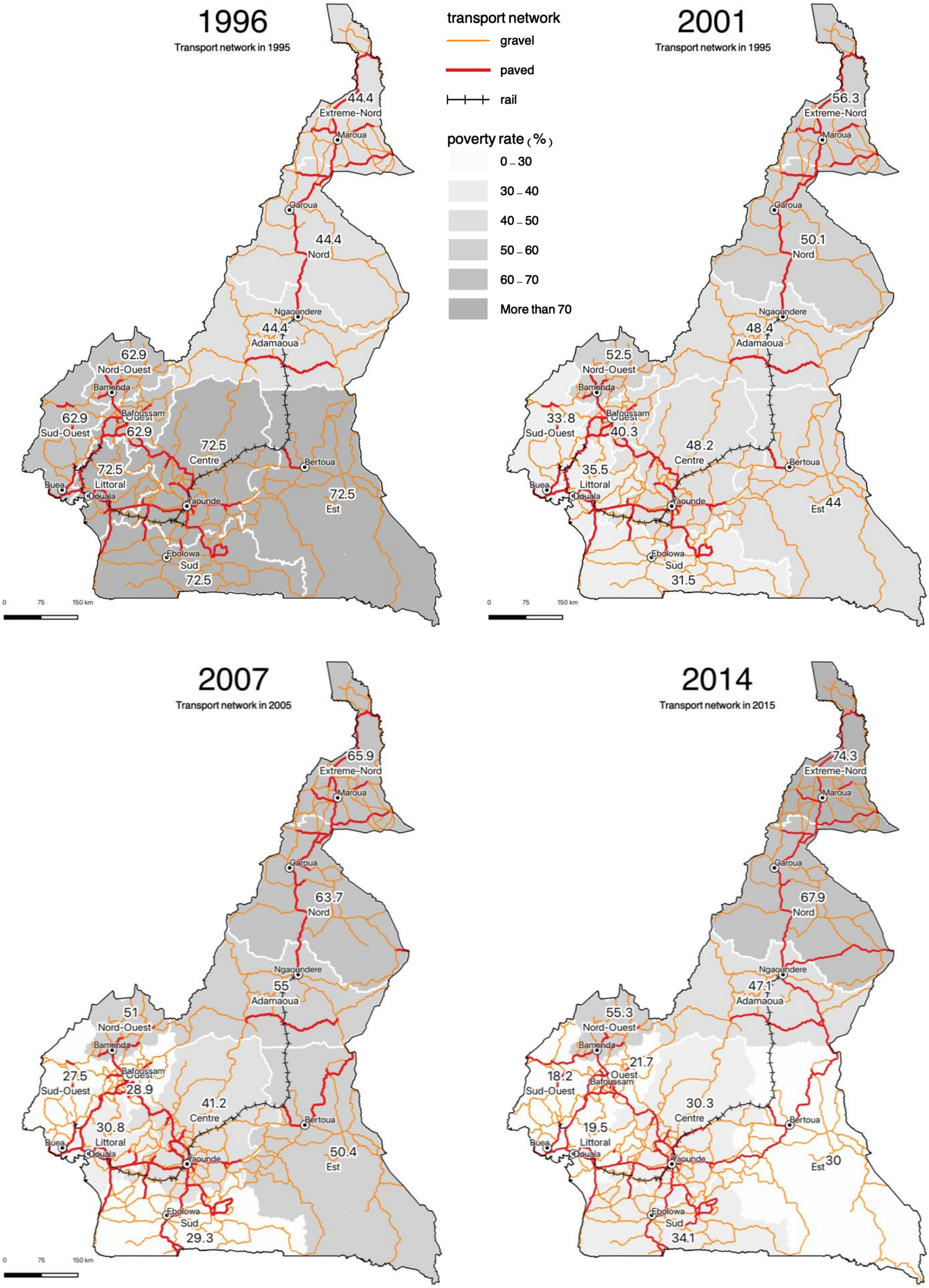


Figure 6.25. Poverty rates by region in Cameroon in selected years (%) (Source: Author based on ECAM I, II, II and IV)

The figures show very different developments between regions and a trend towards increased regional disparities. Poverty rates in the two major cities, Douala and Yaoundé, are given separately as they are far below the average of the region that contains them. We observe a positive evolution in the regions of the Est, Littoral, Ouest, Centre and Sud-Ouest. In the Nord-Ouest, the Adamaoua and the Sud-Ouest the situation does not improve or slightly worsens. Finally, in the Extreme-Nord and the Nord poverty rates have significantly increased since 1996 and, in 2014, are markedly the two regions with the highest proportion of poor (figure 6.25).

We look at the evolution of the poverty rates together with the evolution to the fractal index F to find out whether there is a correlation between poverty and transport infrastructure provision. For this purpose, we consider the index obtained for the asphalt network only. The paved network is a better indicator because, as we have established in previous sections, from 1995, the coverage of the transport network does not increase significantly, and it is the quality of roads that has more impact on economic growth and population's well-being by reducing travelling time and operating costs. In table 6.14 and figure 6.26, we have ranked the regions according to the F index for the paved network with values obtained in section 6.2.2.

	1995	**2005**	**2015**
	*P^0.75*S^0.25*	*P^0.61*S^0.39*	*P^0.4*S^0.6*
1	Sud	Sud	Ouest
2	Adamaoua	Ouest	Sud
3	Centre	Littoral	Littoral
4	Ouest	Centre	Sud-Ouest
5	Littoral	Nord	Adamaoua
6	Nord	Extreme-Nord	Centre
7	Extreme-Nord	Adamaoua	Extreme-Nord
8	Sud-Ouest	Est	Nord-Ouest
9	Nord-Ouest	Sud-Ouest	Nord
10	Est	Nord-Ouest	Est

Table 6.14. Region rankings according to F index for the paved network in studied years
(Source: Author)

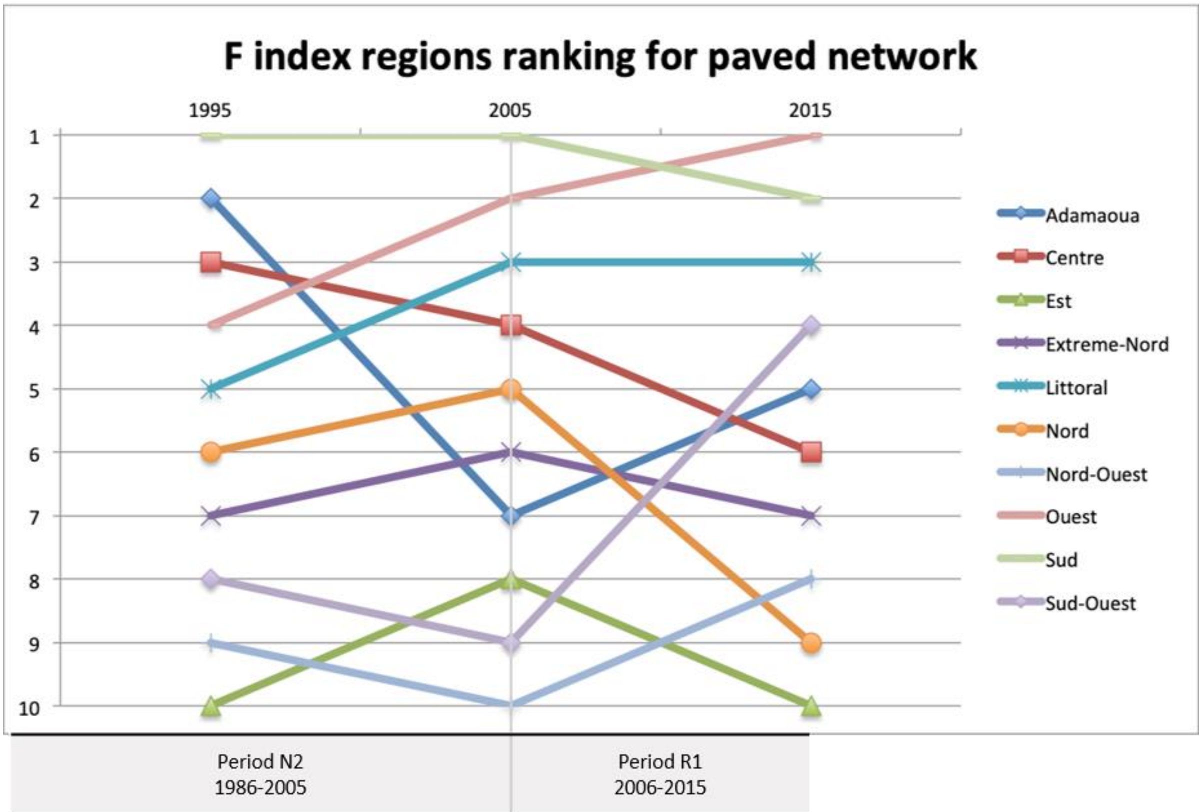


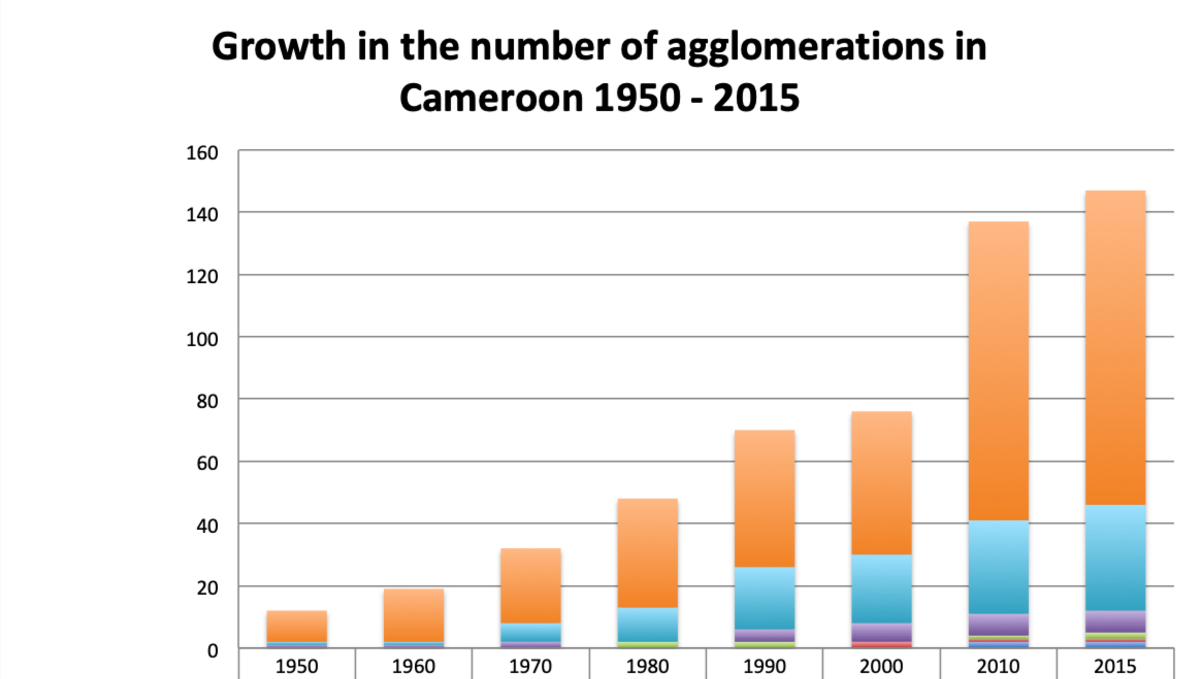
Figure 6.26. Evolution of the region rankings according to F values for the paved network (Source: Author)

With the exception of the Est region, when we compare the paved network in 2015 with the poverty rates in 2014, we observe that the poorest regions are also the ones with the lowest transport infrastructure provision according to the F index for the paved network. This is particularly the case for the Extreme-Nord, the Nord and the Nord-Ouest. On the contrary, regions like the Ouest, the Littoral and the Sud-Ouest with the highest F indices are the ones that have the lowest poverty rates. While this correspondence is not univocal, we observe a certain pattern where the richest regions have the better infrastructure according to their surface and population. In any case, the policy implications of this finding are to be assessed together with the conclusions drawn in previous analysis. This is what we intend to do in the conclusions of this chapter.

6.3. Urban centres growth and accessibility

Compared to the rest of Africa, Cameroon is a highly urbanised country. Not just because, in 2018, 56,4% of the population lived in urban areas, while the average in Sub-Saharan Africa was 40,2%,[101] but also due to the number of midsized and big cities. While many countries have most of the urban population concentrated in the metropolitan area of the capital, Cameroon has more than 20 cities of more than 50.000 inhabitants and two of more than 2 million.

From 1950 to 2015, Cameroon went from 12 cities of more than 10,000 inhabitants to 147 (figure 6.27). The understanding of the urban organisation is essential to complete the analysis conducted in the previous chapters based on the population density per regions and departments. For most of these administrative partitions, the territorial features are determined by the existence and the size of urban centres.



	1950	1960	1970	1980	1990	2000	2010	2015
10,000 - 30,000	10	17	24	35	44	46	96	101
30,000 - 100,000	1	1	6	11	20	22	30	34
100,000 - 300,000	1	1	2	0	4	6	7	7
300,000 - 1 million	0	0	0	2	2	0	1	2
1-2 million	0	0	0	0	0	2	1	1
Above 2 million	0	0	0	0	0	0	2	2

Figure 6.27. Evolution of the number of agglomerations in Cameroon between 1950 and 2015 (Source: Africapolis[102])

[101] United Nations Population Division. World Urbanization Prospects: 2018 Revision.

[102] Africapolis.org is produced by the Sahel and West Africa Club (SWAC) in collaboration with e-geopolis.org. [Downloaded the 7th of April 2020 from https://africapolis.org]

In the colonial period, the desire to cover the whole country in a relatively uniform grid led to an over-representation of the administrative function in the less urbanised regions (Marguerat, 1973). Most of those administrative centres have kept their role until present. The choices of location made by the colonial powers administration determined the networks of large-scale trade, obviously with the constraints imposed by the means of transport (railways, river ports, etc.). In the post-colonial period, the strong political influence on the organisation of the cities remained. However, economic hierarchisation dynamics progressively appeared. It helped some urban centres to grow more than others, irrespective of the central government's willingness to rebalance the territory with selective investments. Table 6.15 contains the population for selected years in the twenty-three cities that in 2005 had more than 50,000 inhabitants. These figures have been represented in figure 6.28, except for Yaoundé and Douala, whose spectacular growth does not allow for a representation in the same chart. However, we have illustrated this growth in the maps included in figure 6.29. It can be seen that, indeed, the representation of Yaoundé and Douala is difficult due to their exponential growth in relation to the size of the rest of the cities in the country.

	1967	1976	1987	2005	2015
Yaoundé	90,000	313,706	649,252	1,817,524	3,124,485
Douala	200,000	458,426	809,852	1,907,479	2,994,179
Bamenda	18,700	48,111	110,142	269,530	431,680
Bafoussam	19,928	62,239	112,681	239,287	355,681
Garoua	15,282	63,900	141,839	235,996	308,516
Maroua	31,422	67,187	123,296	201,371	260,692
Ngaoundéré	19,041	38,840	78,062	152,698	217,369
Kumba	31,000	44,175	70,112	144,268	210,914
Buea	9,300	24,584	32,871	90,088	153,150
Bertoua	5,194	14,982	43,402	88,462	128,682
Kumbo	9,000	12,533	33,353	80,212	127,298
Limbe	22,300	26,988	44,561	84,223	117,745
Kousseri	2,386	12,456	53,713	89,123	116,341

Nkongsamba	37,368	70,464	85,420	104,050	115,435
Kribi	4,319	11,261	21,507	59,928	102,770
Foumban	23,392	33,737	57,271	83,522	101,870
Tiko	9,800	14,810	23,559	60,796	100,131
Ebolowa	17,582	18,239	34,771	64,980	90,304
Dschang	11,212	17,814	35,717	63,838	86,660
Sangmelima	5,442	14,758	23,261	51,308	77,804
Edea	16,612	25,398	50,609	66,581	76,921
Guider	6,656	17,197	32,775	52,316	66,915
Mbalmayo	12,649	22,075	35,390	52,813	65,200

Table 6.15. Number of inhabitants for selected years in cities with more than 50,000 inhabitants in 2005

In figure 6.28 we can appreciate a general trend towards exponential growth rates. The only exception is Nkongsamba which keeps a linear growth and loses relative weight in comparison to the nearby cities of Bafoussam and Dschang. As we have seen, Nkongsamba's relative decline is linked to the abandoning of the railway operations. The cities with the highest growth rates are Bamenda and Bafoussam. Both cities overtook Garoua during the 1990s and Bamenda has become the third largest city in the country. Other major cities are Maroua and Ngaoundéré in the north of the country and Kumba in the Sud-Ouest. What is most significant in this table is that the Bamenda-Kumbo group of cities grows above the rest. Bamenda and Bafoussam grew especially from 1985, from the N2 period onwards.

Besides the Yaoundé and Douala bicephalic structure, it is important to analyse the emergence of other urban systems. In the western grassfields, the development of Bafoussam and Bamenda originates from the Bamileke social structure (facilitated, in the case of Bamenda, by the British colonial institutional heritage) (Marguerat, 1973). Therefore, their growth and autonomy were made possible, not only by their isolation, but also by the dynamism of their indigenous bourgeoisies. In fact, the intensity of the urbanisation in this part of the country is not limited to these two cities. It is characterised by a dispersed pattern covering multiple small urban centres which built-up areas have expanded and merged into one large agglomeration. This urban footprint in the western Cameroon can be visualised in the Africapolis.org website, which combines demographic data, satellite and aerial imagery and other cartographic sources (figure 6.30). The urban continuum in the Bamileke area also integrates the city of Dschang, in addition to multiple cities of less than 50.000 inhabitants. North of Bamenda, on what is known as the Ring

Road (because it starts and ends in Bamenda), there are also many urban centres, the most prominent of which is Kumbo.

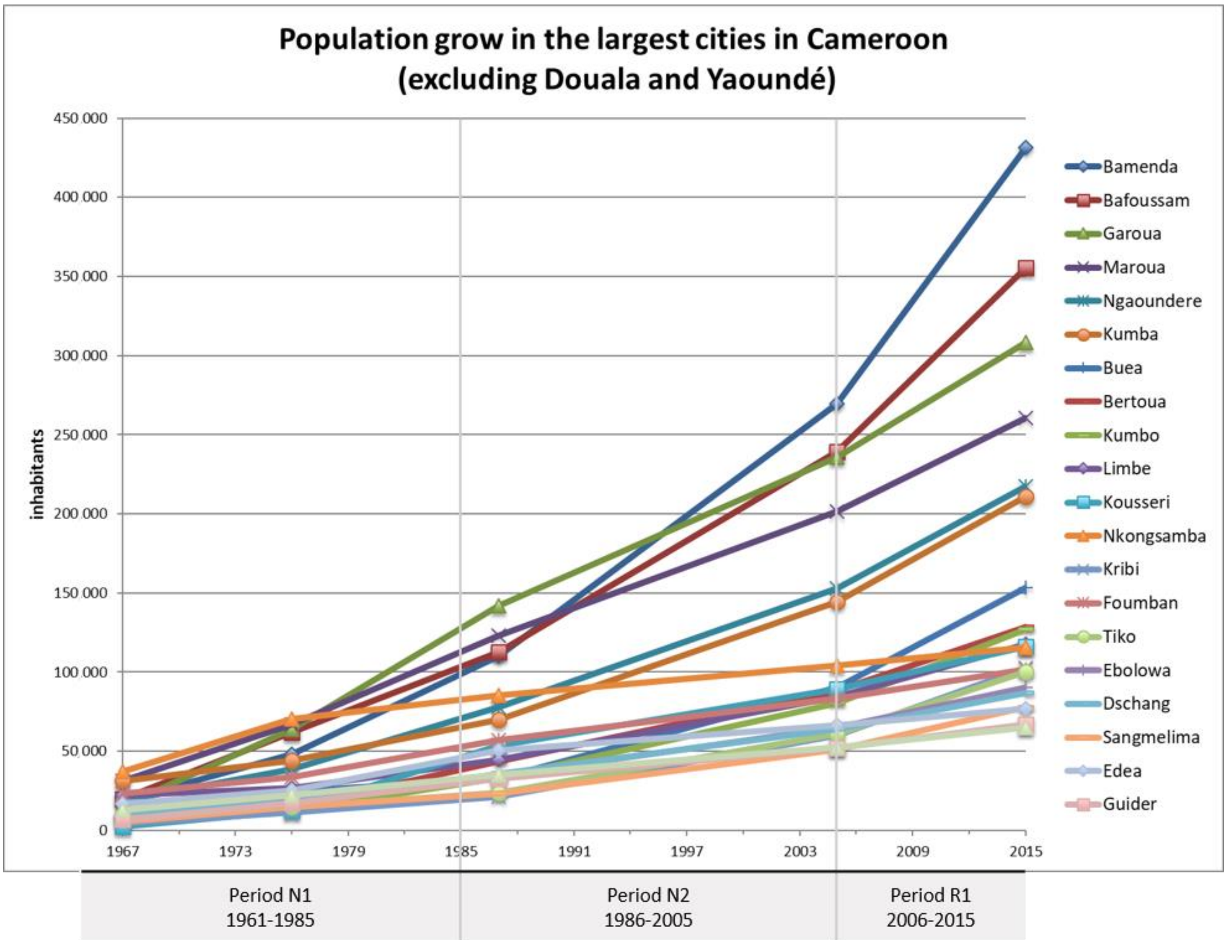


Figure 6.28. Population growth in the cities with more than 50,000 inhabitants in 2005, excluding Yaoundé and Douala (Source: Author)

The expansion of the cities in the north part of the country results from the high natural population growth and the rural-urban migration. Although the only major resource in the north is cotton, cities have the advantage of remoteness from Yaoundé and Douala and the existence of a trade-oriented ruling class. In the case of Garoua, the historical port infrastructure endowment and the administrative weight is strengthened by the dynamic local private sector in the hands of the hausa-fulbe people (Marguerat, 1973). As we have seen, the rise of Ngaoundéré is the result of the end of the Trans-Cameroon railway. In the Extreme-Nord, Maroua, thanks to its regional capital status, has been able to withstand strong competition from major urban centres in its catchment area, notably from Guider, Kaélé, Mokolo, Mora, and Yagoua.

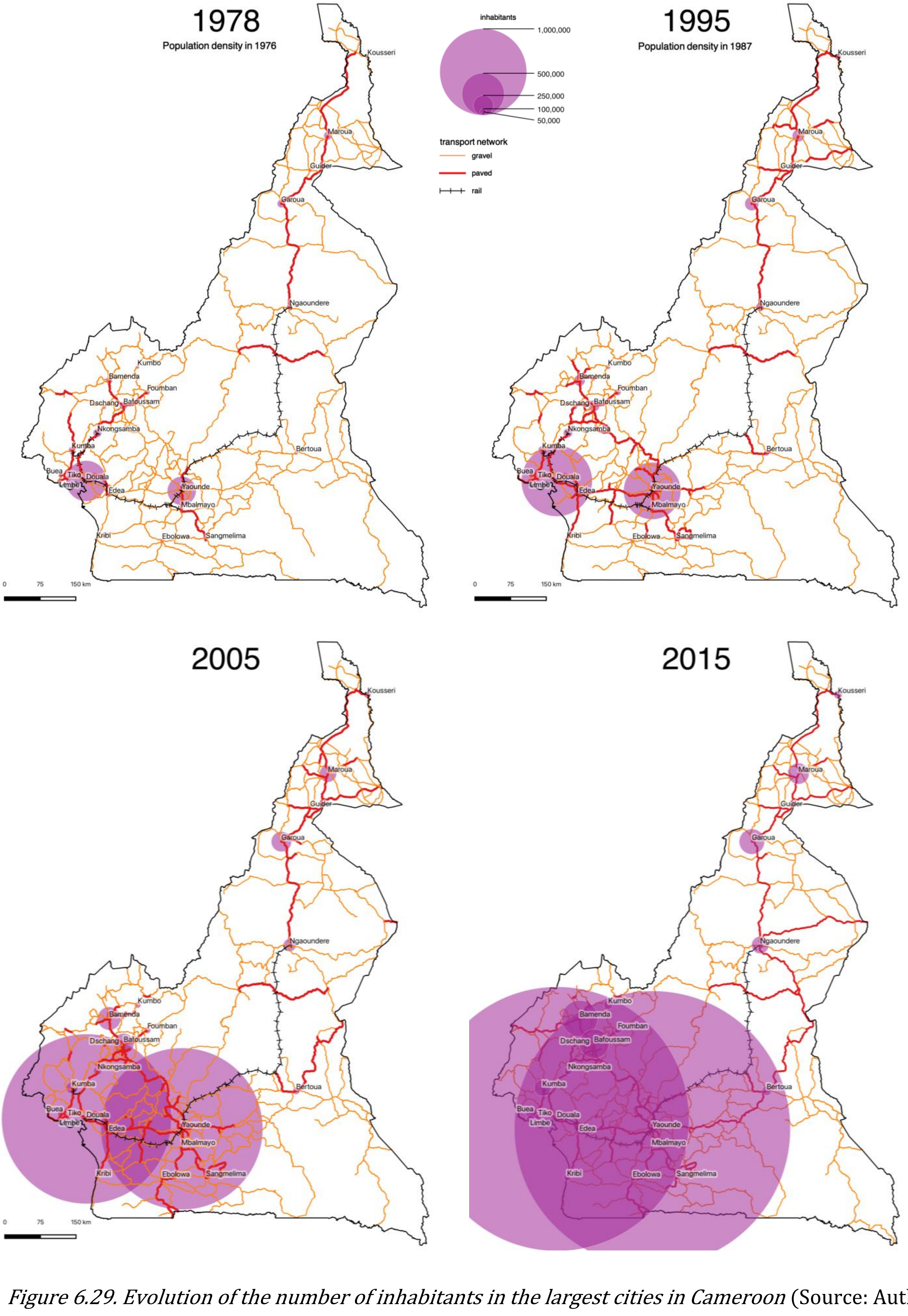


Figure 6.29. Evolution of the number of inhabitants in the largest cities in Cameroon (Source: Author)

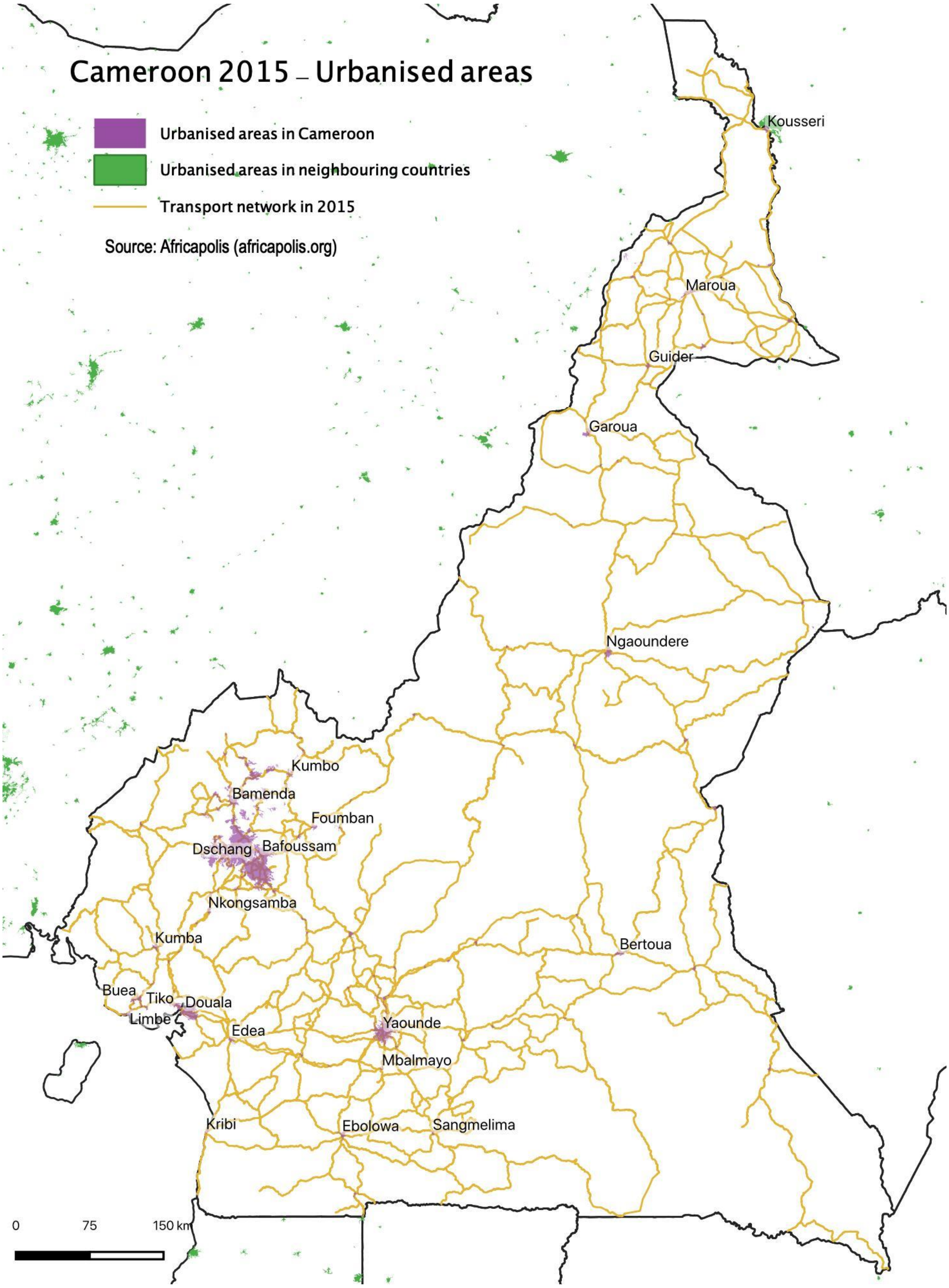


Figure 6.30. Urban agglomerations in Cameroon in 2015 (Source: Africapolis)

In the Sud-Ouest, on the fertile slopes of Mount Cameroon, there is also an important urban network under the strong influence of Douala but with independent dynamics. Actually, the Germans identified this region as the one having more economic potential and the history would have been different if Douala had not been selected as the origin of the central railway to Yaoundé. The main centres of this urban system are Kumba, Buea, Limbe and Tiko. Kumba is today Cameroon's biggest city that is not a regional capital. Historically, Kumba has been a major transport link between the Anglophone and the Francophone Cameroon and still today connected by railway to Mbanga. The main export crop in the area is cocoa. More to the south, the urban dynamism is fostered by the large plantations of oil palms, rubber, cocoa, tea, bananas and plantains. The public agro-industry Cameroon Development Corporation (CDC) employs thousands of workers who live with their families in compounds or towns close to the agricultural fields.

Figure 6.31 includes a succession of maps obtained from the above-mentioned website Africapolis.org. They represent the urban centres indicated in the table in figure 6.27. In this case, the size of the mapped urban centres is not proportional to the populations, although there is a correspondence between the size of the symbol and the size of the city. The objective of compiling this series of maps is to illustrate how the urban centres have evolved and clustered over time.

Overall, we can observe the existence of four main urban systems in Cameroon:

- In the north, the Maroua-Garoua axis, encompassing secondary centres such as Guider, Kaélé, Mokolo, Mora, and Yagoua.
- In the centre, the metropolitan area of Yaoundé, which embraces several important cities in its area of influence, including, to the south, Mblamayo, Ebolowa and Sangmelima.
- In the west, the pair Bamenda-Bafoussam, surrounded by a myriad of towns that have grown and merged into what today constitutes a large urban agglomeration.
- In the littoral, the city of Douala, which exerts a significant influence on a large area where we can identify two urban sub-systems:
    - To the south, where Edea, and even Kribi, function as an appendix subordinated to the economic capital.
    - To the west, where the Anglophone cities of Limbe, Tiko, Buea and Kumba surrounding Mount Cameroon, enjoy a certain autonomy from Douala thanks to their economic dynamism and the linguistic differential.

Outside these four urban systems, it is worth noting Bertoua and Ngaoundéré, which are cities characterised for being regional centres for the eastern and central parts of the country, the less populated ones, but, most importantly, for being crucial stages in the routes between the south and the north of Cameroon.

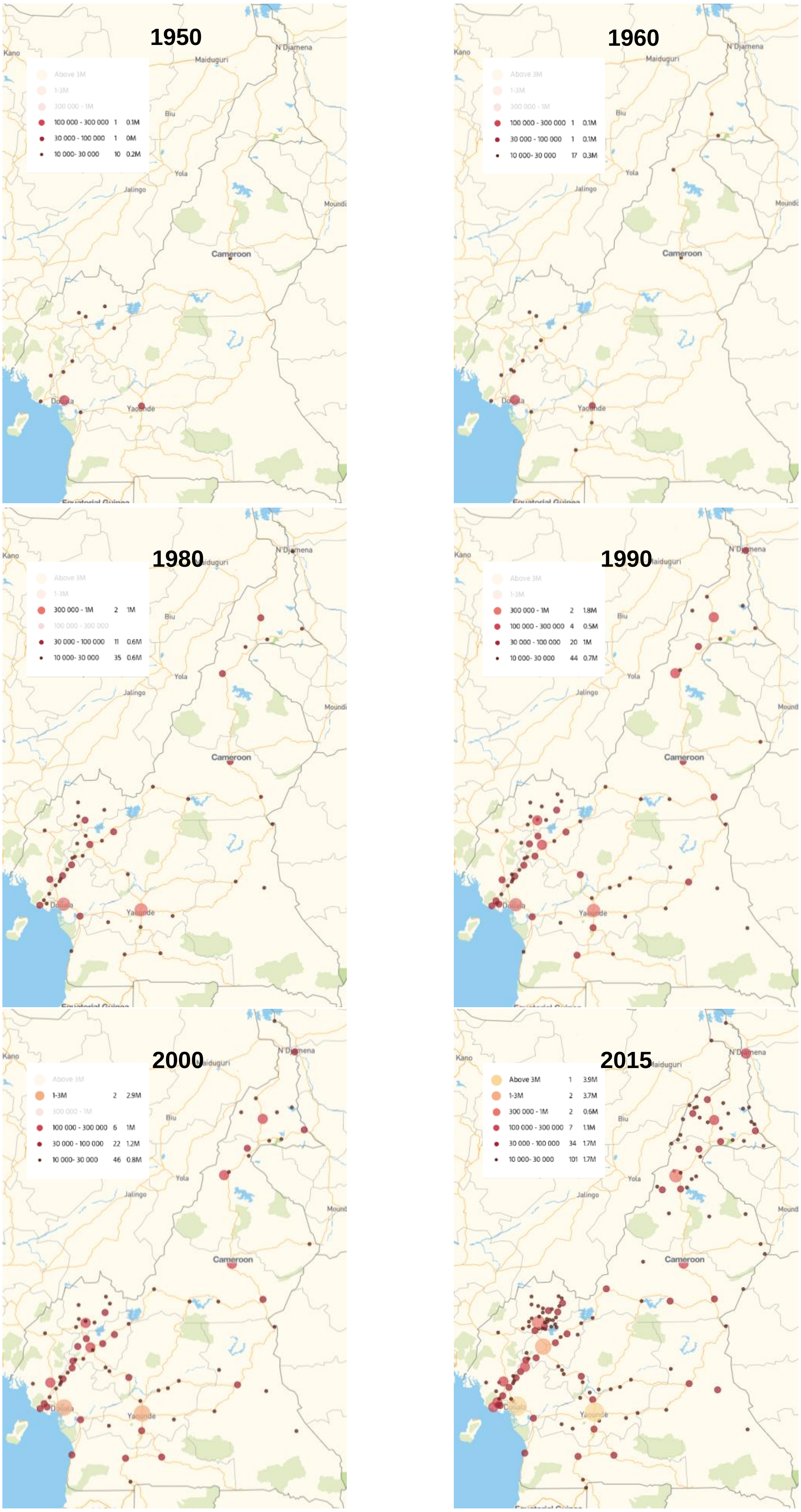


Figure 6.31. Evolution of the urban agglomerations of above 10,000 inhabitants in Cameroon between 1950 and 2015 (Source: Africapolis)

Considering this urban system, we examine how the transport network around the Cameroonian largest cities has evolved over the years. With the same GRASS GIS software used in previous sections, we have calculated the length of the network that can be travelled within two hours from each of the major urban centres. The values for the selected years are in table 6.16 and represented in figure 6.32.

	1930	1955	1966	1978	1995	2005	2015
Yaoundé	375.0	454.3	455.6	841.0	1226.1	1264.0	1626.6
Edea	96.6	331.8	183.1	596.0	877.1	914.9	966.5
Bertoua	0.0	395.6	299.6	526.4	579.9	651.4	871.8
Maroua	53.1	297.5	715.1	860.2	916.4	908.0	710.9
Sangmelima	95.7	207.9	262.0	365.6	498.6	608.0	710.4
Bafoussam	125.3	201.0	250.7	606.3	664.9	525.6	549.8
Ngaoundéré	79.6	239.7	179.7	426.4	410.8	320.2	454.4
Ebolowa	100.1	359.1	230.1	431.5	389.9	600.1	441.3
Kumba	98.3	220.4	487.2	376.2	382.0	557.8	408.2
Bamenda	80.1	363.9	237.8	399.5	578.1	348.3	394.9
Guider	104.3	120.6	168.4	264.0	407.2	270.8	374.2
Kribi	60.0	211.0	280.1	296.8	303.6	380.8	341.9
Nkongsamba	187.5	278.0	161.0	423.2	349.9	175.4	320.6
Mbalmayo	74.1	243.1	383.3	479.9	475.5	394.9	314.3
Garoua	101.1	263.2	355.5	441.5	485.2	398.3	312.7
Kousseri	0.0	40.0	102.3	293.7	324.3	368.8	262.7
Foumban	33.2	88.8	96.4	269.7	286.6	351.4	201.4
Kumbo	80.0	167.1	98.1	197.5	242.9	206.5	195.6
Dschang	73.2	131.1	76.7	123.9	137.6	231.1	190.7
Douala	275.0	260.2	435.6	346.5	297.2	109.0	156.9
Tiko	15.8	15.4	39.1	42.7	41.5	128.5	116.3

Buea	40.2	46.8	48.3	90.5	90.0	85.3	105.0
Limbe	9.3	64.2	63.5	63.8	63.8	84.0	88.8
Total	2157,6	5000,9	5609,1	8762,9	10029,0	9882,9	10116,1

Table 6.16. Length of the network that can be travelled within 2 hours from each of the largest cities (Source: Author)

As their access is not radial, the length of the network travelled from cities located on the coast (Kribi, Douala, Tiko, Limbe), cul-de-sac (Buea) or along corridors (Nkongsamba, Mbalmayo, Kousseri, Foumban, etc.) is shorter than the radial networks from the cities that are in the centre of a region (Yaoundé, Édea, Bertoua, Maroua, etc.). In this way, Yaoundé is surrounded by the best network, offering by far the longest travelling possibilities. This result corresponds with the highest provision of transport infrastructure and paved roads in the Centre region, as calculated in the previous sections. Other cities with high values and positive trends are Edea, Bertoua and Sangmelima. On the negative side, we observe two groups. First, cities with good surrounding networks but with declining lengths, which means that the network is not sufficiently maintained and has deteriorated. Second, urban centres that, over the years, have barely not benefited from an expansion or improvement of the transport infrastructure around them. In this last group, in the bottom part of table 6.16 and of the chart in figure 6.32, we observe the cities of Tiko, Buea and Limbe.

Given the importance of the city, the case of Douala is startling. Considering its coastal situation, it is understandable that the access routes are limited and, consequently, that the accessible network within 2 hours is short. However, the declining values from 1966 show a concentration of the investments along a limited number of corridors (to Yaoundé and to Bafoussam) and the failure to maintain the proximity network, in particular, the route heading to Yabassi. Other important cities where, in the last decades, there has been a significant decline of accessibility are Maroua, Garoua and Mbalmayo. In the case of cities like Bafoussam, Bamenda, Ngaoundéré, Guider and Nkongsamba, there was an important deterioration of accessibility between 1995 and 2005, but this situation was overcome during the following decade.

In the sequence in figure 6.33, the maps indicate in green the sections of the network that can be travelled within two hours from each city for the studied years. Around the triangle Douala-Yaoundé-Bafoussam/Bamenda, in the Sud and in the Extreme-Nord most of the network is within 2 hours from any big city. This situation was attained already in the 1970s. On the contrary, there are vast areas in the Adamaoua and the Centre region that are far in time-distance from any major urban centre. While in these two regions, the physical distance to more dense areas explains this difficult accessibility, it is worth mentioning the Nkam department, which covers the surface in the centre of the triangle Douala-Yaoundé-Bafoussam/Bamenda. In that case, it is the condition of the road that determines the low levels of accessibility, as the actual physical distances could be travelled easily if roads were in good condition. This circumstance also applies to the areas situated along the Nigerian border in the Sud-Ouest and Nord-Ouest regions.

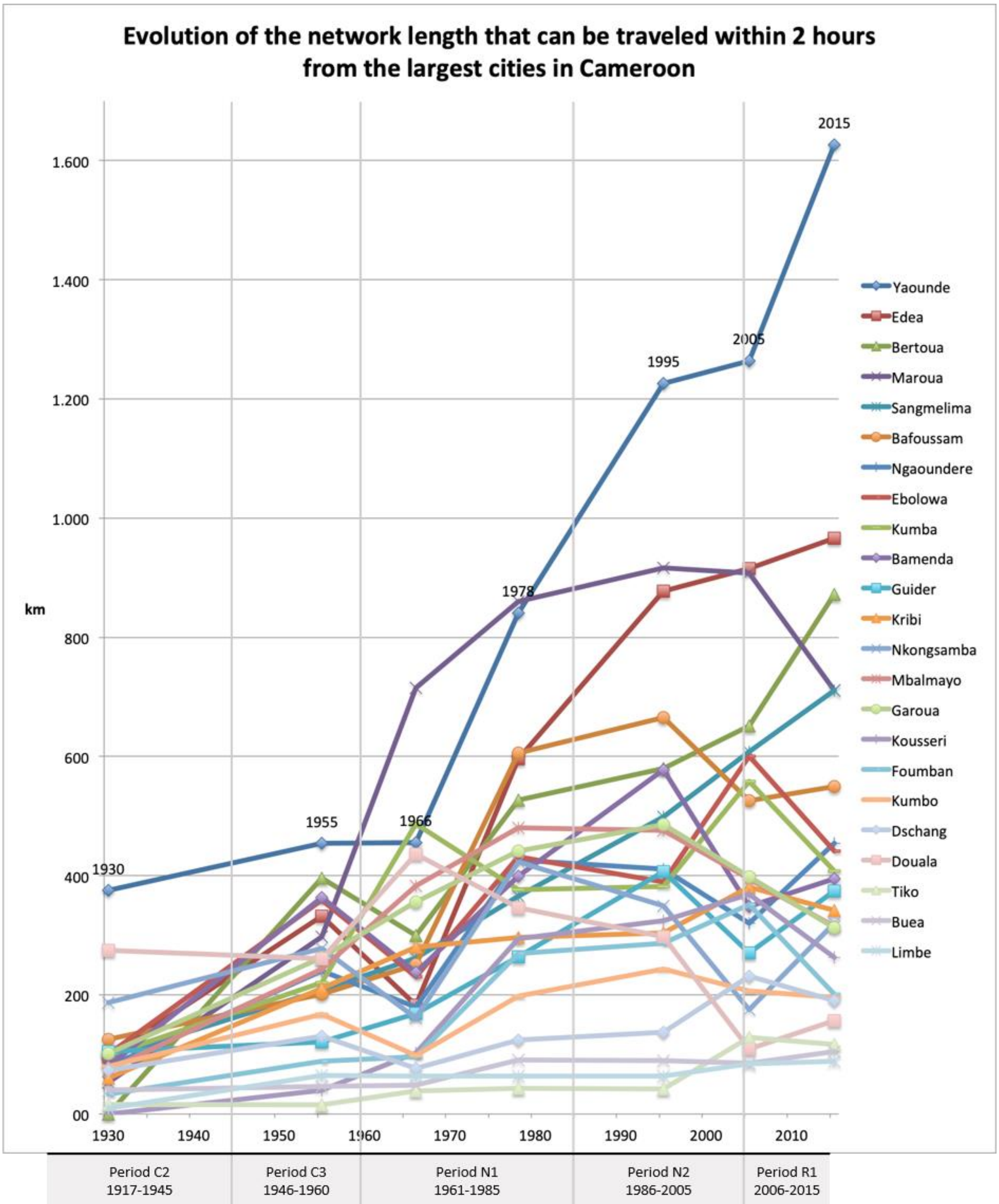


Figure 6.32. Evolution of the length of the network that can be travel within 2 hours from each of the largest cities (Source: Author)

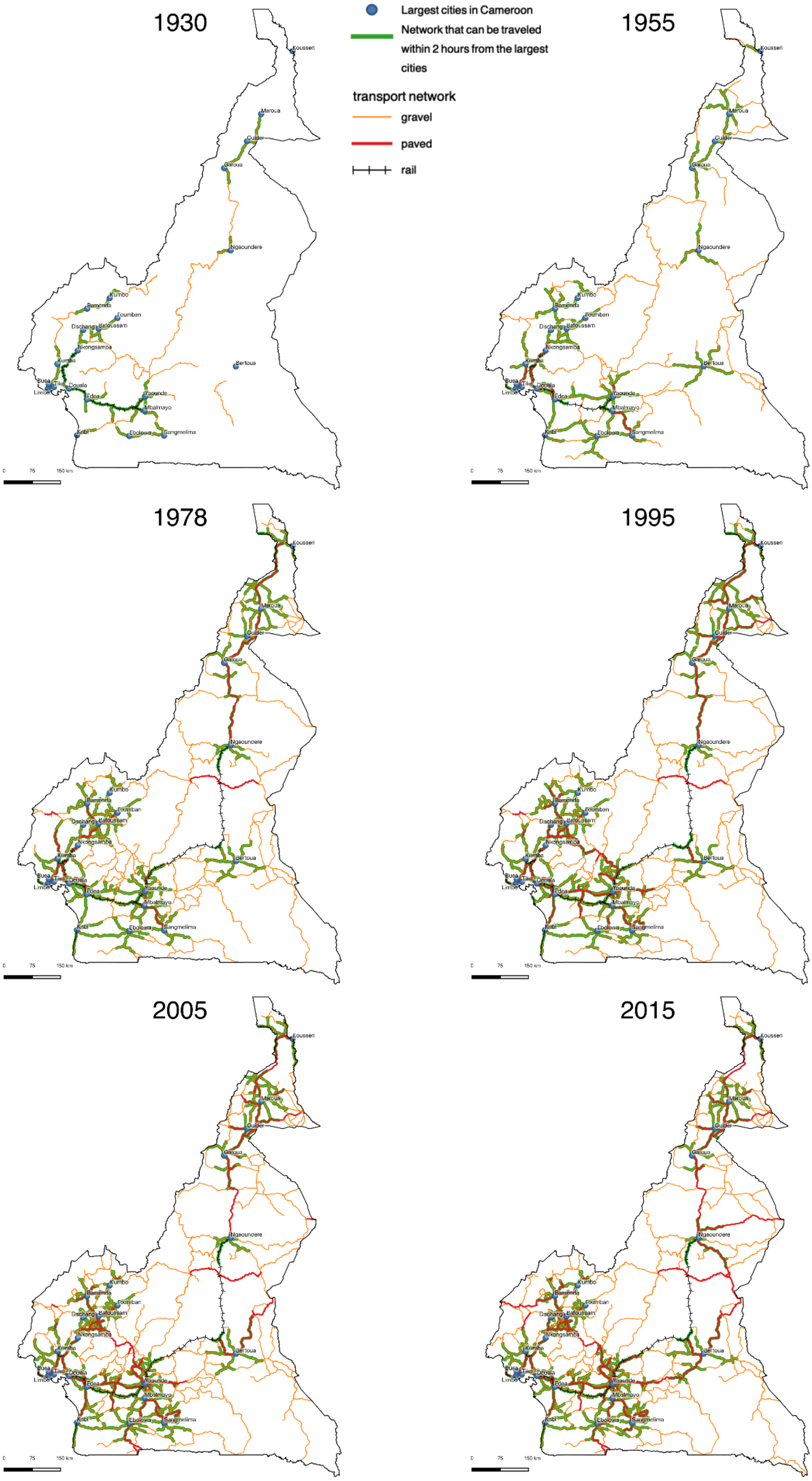


Figure 6.33. Maps for studied years indicating the part of the network that can be travelled within two hours from the largest cities (Source: Author)

It is also important to recall the impact of the relief enabling/disabling longer trips from the cities. For instance, the high slopes of the falaise at the exit of Ngaoundéré, on the road to Garoua, greatly slows down the speed of vehicles, especially heavy goods vehicles. If those steep roads are in bad condition, the situation becomes even more difficult. As a result, the section Ngaoundéré-Garoua, which is among the ones with highest centrality as we can observe in figure 5.10, is not in the 2h network since 2005.

This reasoning can be done in the opposite way thanks to the fact that, in figure 6.33, we have superimposed the asphalted roads on the green lines that show the routes that can be travelled in less than 2 hours. In this way, we can see which parts of the network around cities are asphalted and which are not, and thus determine which road sections should be prioritised for upgrading. This can be seen very clearly in the 2005 and 2015 maps for the towns of Bertoua, Ngaoundéré, Garoua and Maroua, where, despite an improvement in that decade, there are still unpaved roads giving direct access to the urban centre.

The analysis of the transport network looking at the urban system provides new insights into how it has been shaped over the years. Predictably, it has confirmed that the largest cities in the most populated areas are better transport serviced. The overconcentration of investments around Yaoundé is even more salient under this analysis. Apart from it, we can confirm the findings obtained in previous sections, where we concluded that the population is progressively less determinant when making decisions about the expansion of the network. We have illustrated this trend by showing the stagnation or even deterioration of the situation of the network surrounding Douala, Bafoussam, Bamenda, Maroua and Garoua. Only Yaoundé seems to escape this phenomenon. In other words, it means that decision-making in transport investment has neglected the network close to where most of the population lives, the cities.

6.4. Conclusions of the territorial analysis: the decreasing weight of the population factor

The dilemma of where to invest has always existed against the backdrop of lack of means. In the three colonial periods, C1 (1884-1916), C2 (1917-1945) and C3 (1946-1960), despite the official narrative of occupying all the territory possessed, the reality was that the public money mobilised was insufficient and, finally, most of the investments remained concentrated in the most productive areas. As we have seen, in period C3 (1946-1960), the FIDES era, asphalting the roads around Douala was probably the right choice in view of the colossal investments that were needed. From period N1 (1961-1985), since the birth of the new multi-ethnic country, the balance between the provinces has always been a major political imperative, whether official or unofficial, clearly expressed in the Second Five-Year Plan (1965-1971) and especially in the Third Five-Year Plan (1971-1976). The history of the transport network in Cameroon is one of deciding whether investments should be made where the population lives, and therefore where the infrastructures provide the greatest economic returns, or where they cover the largest possible territory to ensure an inter-regional balance. Our analysis shows a tendency towards prioritising territorial coverage and, therefore, an increased number of investments serving low-density areas while some of the most central links have been neglected.

To illustrate in more detail the loss of weight of the population factor in transport infrastructure decision-making, we have combined the data obtained from the various graphs above. In figure 6.34, we have represented the evolution of the length of paved roads together with the length of the trips that can be travelled within two hours from the twenty-three biggest cities.

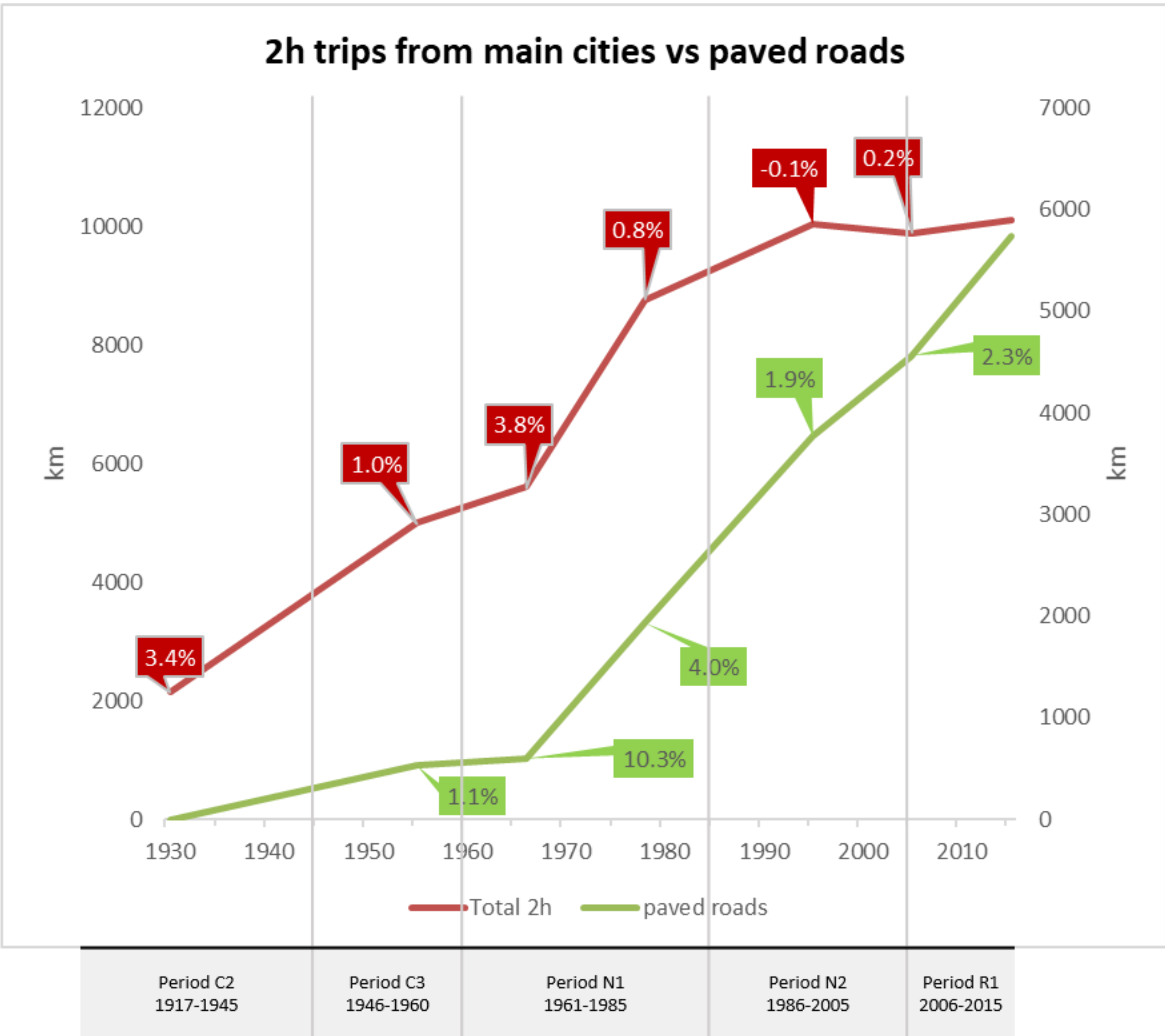


Figure 6.34. Evolution of the length of the paved roads in relation to the length of the trips that can be travelled within 2 hours from the main cities (Source: Author)

We observe that, in periods C2 and C3, the growth of the paved roads is accompanied by an increase of the length that can be travelled from the main cities within 2 hours. The same happens in period N1, where the asphalt network grew the most, which also resulted in improved accessibility around the cities. However, starting in period N2, while the length of paved roads increased at an average annual rate between 2% and 4%, the length of the trips around the cities stagnated and even decreased. A plausible interpretation is that the paving of the new roads has taken place far from the main cities.

This trend can also be observed when overlapping the evolution of the 2-hours trips from the main cities with the evolution of the population weight 'p-paved' obtained from the fractal index F for paved roads (figure 6.35). As we have explained, for the paved network we can only do these F index calculations from 1995 because, until then, there were regions without any paved road. Despite this limitation, if we look at the end of period N2 and period R1, we can clearly see that the stagnation of the length of the 2-hours trips from the main cities (red line) happens with the drastic decline of the weight of the population criteria in the development of the paved network (blue line).

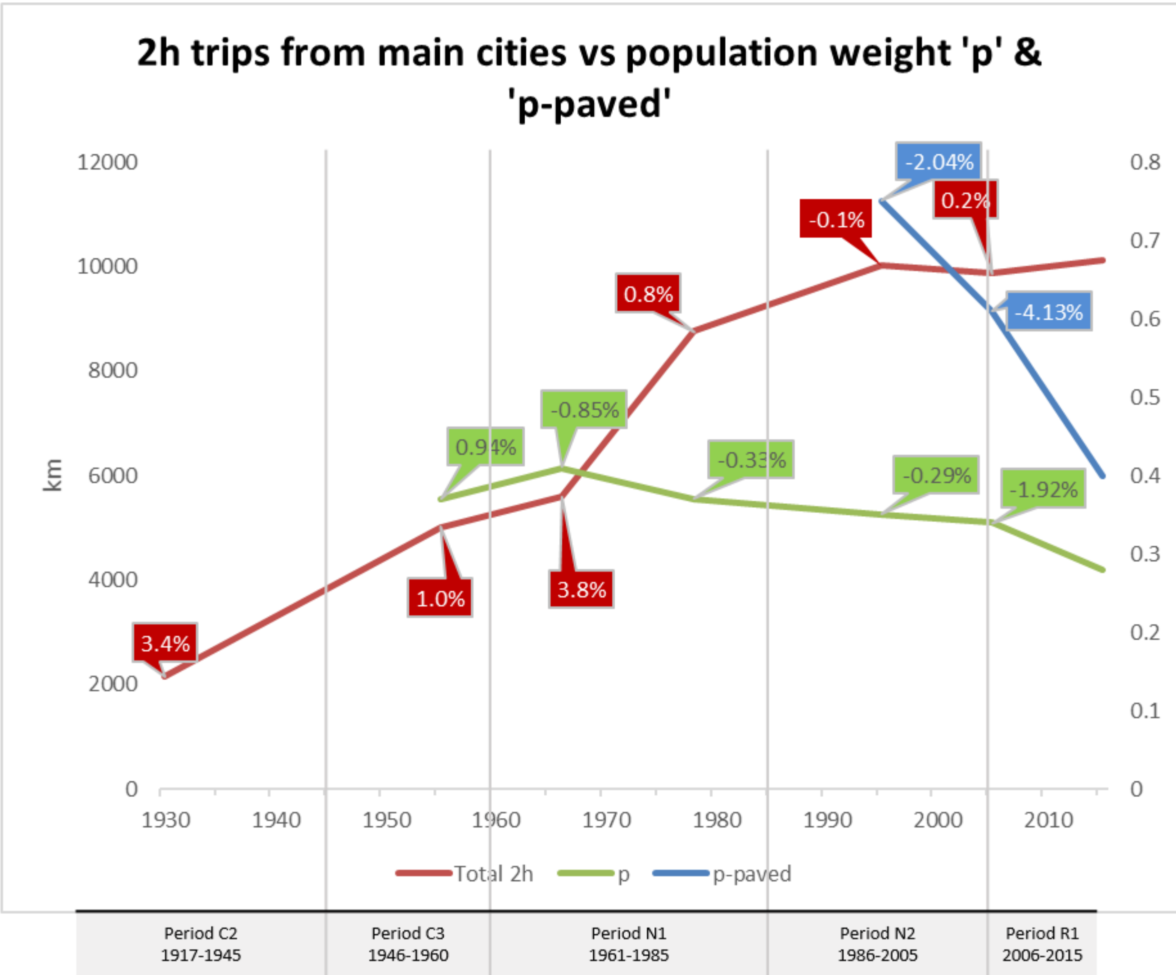


Figure 6.35. Evolution of the length of the trips that can be travelled within 2 hours from the main cities in relation to the population weight p-paved (Source: Author)

In conclusion, the expansion of the transport network has undoubtedly contributed to improve overall connectivity and to have a better territorial coverage, which could be interpreted as a better convergence between the implemented network and the maximum network. However, in a context of scarce financial resources, these choices may not have been optimal in terms of efficiency, understood as the search for a compromise so that the transport network spatially adequately serves economic, political and social needs. The accessibility to the main cities has been neglected. The connection of the different parts of the country cannot avoid passing through areas of low population density. The option of going through the east to link by an asphalt road the north and the south of the country is clearly geared towards an option of giving privilege to cover the territory instead of connecting where people live. It is not necessarily a wrong option because, at that time, financial resources were scarce, and this route serves to give access to the Central African Republic. However, it is not the shortest one. The consequence is that, from 1993, the date it was decided to prioritise the eastern route, it took more than 20 years to complete it. By financing it, the corridor to the north through the most populous areas in the west (Douala-Foumban-Ngaoundéré), as imagined by the Germans, was relegated to a secondary rank. In 2015, the section Foumban-Tibati, the shortest way to open the north by road, was not asphalted yet and there was no plan to do so.

7. Network evolution and investment expenditure in the period 1884-2018

In the preceding chapters, we have analysed the transport network in Cameroon from three different angles. First, we have made a geohistorical analysis that has allowed us to differentiate the six periods that characterise the evolution of the network. Then, we analysed quantitatively the connectivity of the network and the accessibility of the nodes over time. Thirdly, we have studied the configuration of the network according to the surface area of the regions, the population distribution, and the system of major cities. These last two chapters add the financial dimension to the research. The correspondence between public revenue, expenditure on transport infrastructure and the development of the network and its maintenance is studied.

Figure 7.1 and table 7.1 describe the overall evolution of the network over the years, differentiating between asphalt roads, gravel roads, railway, and the total length. Cameroon has experienced two significant expansion phases. Between 1930 and 1955, the network grew from 4,591 km to 10,331 km. This represents an average annual growth rate of 3.3% (see in green in table 4.2). However, the length of the railway did not increase. It is during this period that the first kilometres of road were asphalted, going from 0 km in 1930 to 532 in 1655. The second and most significant expansion phase took place between 1966 and 1978, which corresponds to our period N1. With an average annual growth rate of 4.3%, the length of the network went from around 11,000 km to above 17,000km. This period was characterised by a substantial increase of the paved road network (10.3% per year) and the rail tracks (7.7% per year)

	1930	1955	1966	1978	1995	2005	2015
Total population (million)	2.8	3.9	5.4	7.7	13.9	17.5	23.3
GDP (billion) constant 2010 US$	-	-	5.92	10.98	14.35	22.04	33.59
Length network (km)	4,591	10,331	10,731	17,684	18,659	21,291	22,112
Paved roads (km)	0	532	600	1,937	3,771	4,562	5,732
Percentage paved (%)	0%	5%	6%	11%	20%	21%	26%
Gravel roads (km)	4,145	9,353	9,680	14,642	13,944	15,812	15,462
Railway length (km)	447	447	452	1,105	944	917	917
Annual growth length (%)	NA	**3.3%**	0.3%	**4.3%**	0.3%	1.3%	0.4%
Annual growth paved (%)	NA	NA	1.1%	**10.3%**	**4.0%**	1.9%	2.3%
Annual growth railway (%)	NA	0.0%	0.1%	**7.7%**	-0.9%	-0.3%	0.0%

Length (km)/1,000 km2	9.85	22.16	23.02	37.94	40.03	45.68	47.44
Paved (km)/1,000 km2	0.00	1.14	1.29	4.16	8.09	9.79	12.30
Length (km)/1,000 people	1.64	2.65	1.97	2.31	1.34	1.22	0.95
Paved (km)/1,000 people	0.00	0.14	0.11	0.25	0.27	0.26	0.25

Table 7.1. Main characteristics of the transport network in selected years (Source: Author)

From 1978, the growth of the network slowed down, with an annual rate that at most was 1.3% per year 1995 and 2005. This is understandable when we consider that, as we have indicated earlier, high levels of connectivity have already been reached. Therefore, from that point, what is important is to look at the increase of the length of the paved network. We notice that, with an annual rate of 4% from 1978 and 1995, and of 1.9% and 2.3% respectively in the two subsequent periods, the growth of the asphalted network was below the levels attained in the seventies. In addition, as we have explained in section 4.2.4, the era of structural adjustment programmes saw the closure of several railway sections.

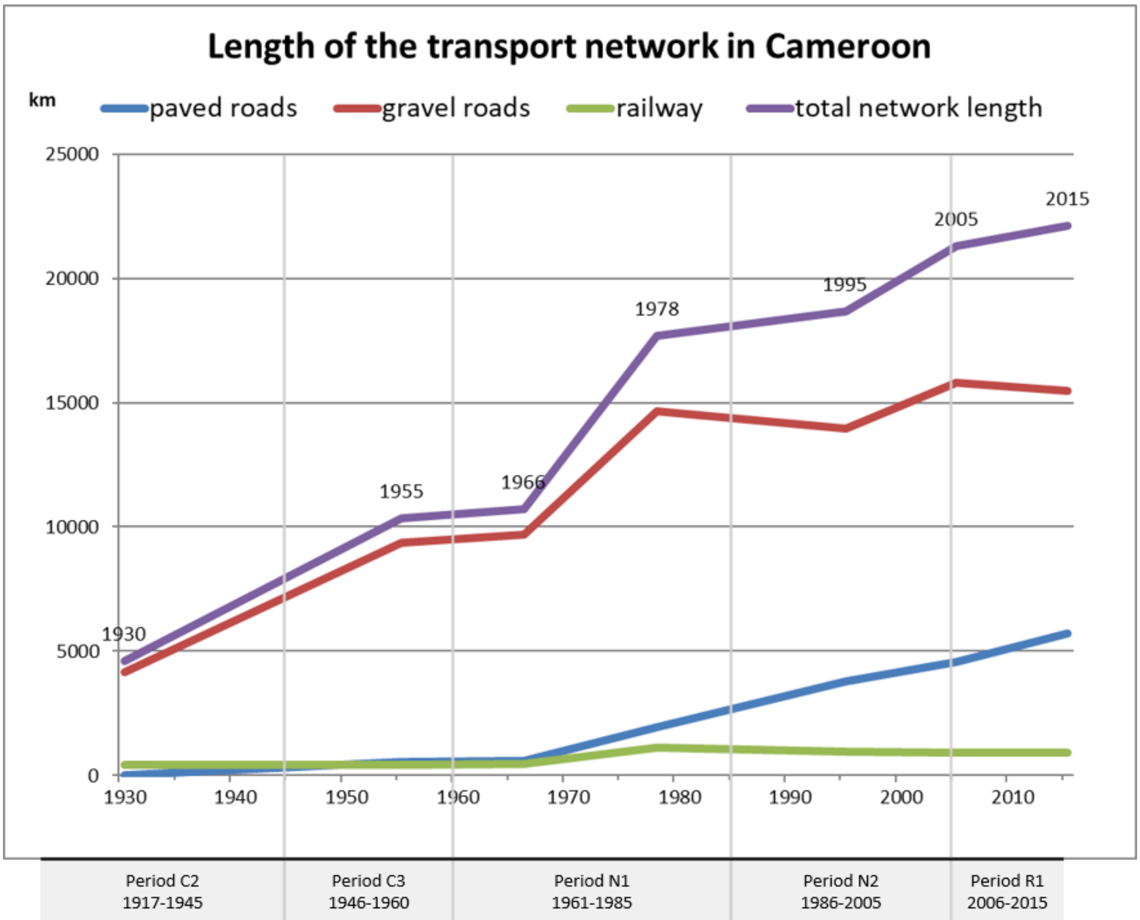


Figure 7.1. Length of the rail and road network over time (km) (Source: Author)

In view of these developments, a few questions arise: does the phases of expansion of the network correspond in time to the transport policies in force at that moment, for instance, regarding the "FIDES plan" or the "Plans quinquennaux"? Are the phases of expansion and stagnation of transport infrastructure in relation to the explanatory timeline proposed in figure 4.2 accurate? Is there a correspondence between the growth in demand and the increase in investment in transport infrastructure? In relative terms, is the level of investment in different periods different? Even if the network has achieved a grid pattern and full connectedness exists, is that of good quality? Over time, does Cameroon have the capacity to maintain the transport infrastructure it builds? To answer these questions, we will look both at the evolution of the network and at financial data.

7.1. The broken mirage of complete connectedness: the lack of paved roads

As we can see from figure 7.1, the expansion of the paved roads has followed a linear progression, but the achievements are, in reality, poor. In 1930, there were no paved roads. Thirty years later, at independence, adding the links from the former French and British territories, the country had about 500-600 km of asphalted roads. In 2015, the network reached 5,862 km of paved roads, or about 27% of the classified network. The proportion of paved roads would be inferior to 5% if we consider the non-classified roads. At the same time, if we consider the asphalted urban roads, the figure will certainly change. However, we have not been able to find accurate historical data about the nature and conditions of the urban network. Although, in this research, we only look at inter-urban classified roads, it is important to bear in mind the existence of this significant length of urban asphalted roads, which adds an additional maintenance obligation.

In figure 7.2, we have put together a sequence of maps for the years studied where we have featured the asphalted roads in red. The evolution of the asphalted network can be clearly observed. Three main milestones can be distinguished. The first is in 1978, when a paved backbone is seen in the north of the country, constituting the extension until N'djamena of the Trans-Cameroon railway. The second is in 1995, illustrated by the completion of the paved triangle Douala-Yaoundé-Bafoussam. The last significant achievement is observed in 2015, as it is in the first map where we can observe that a continuous asphalted road can be travelled from Douala to the Extreme-Nord. In reviewing all these years, we observe that, despite these accomplishments, the red lines are far from entirely covering the country and that vast regions remain underserved, in particular in the Adamaoua and in the Est.

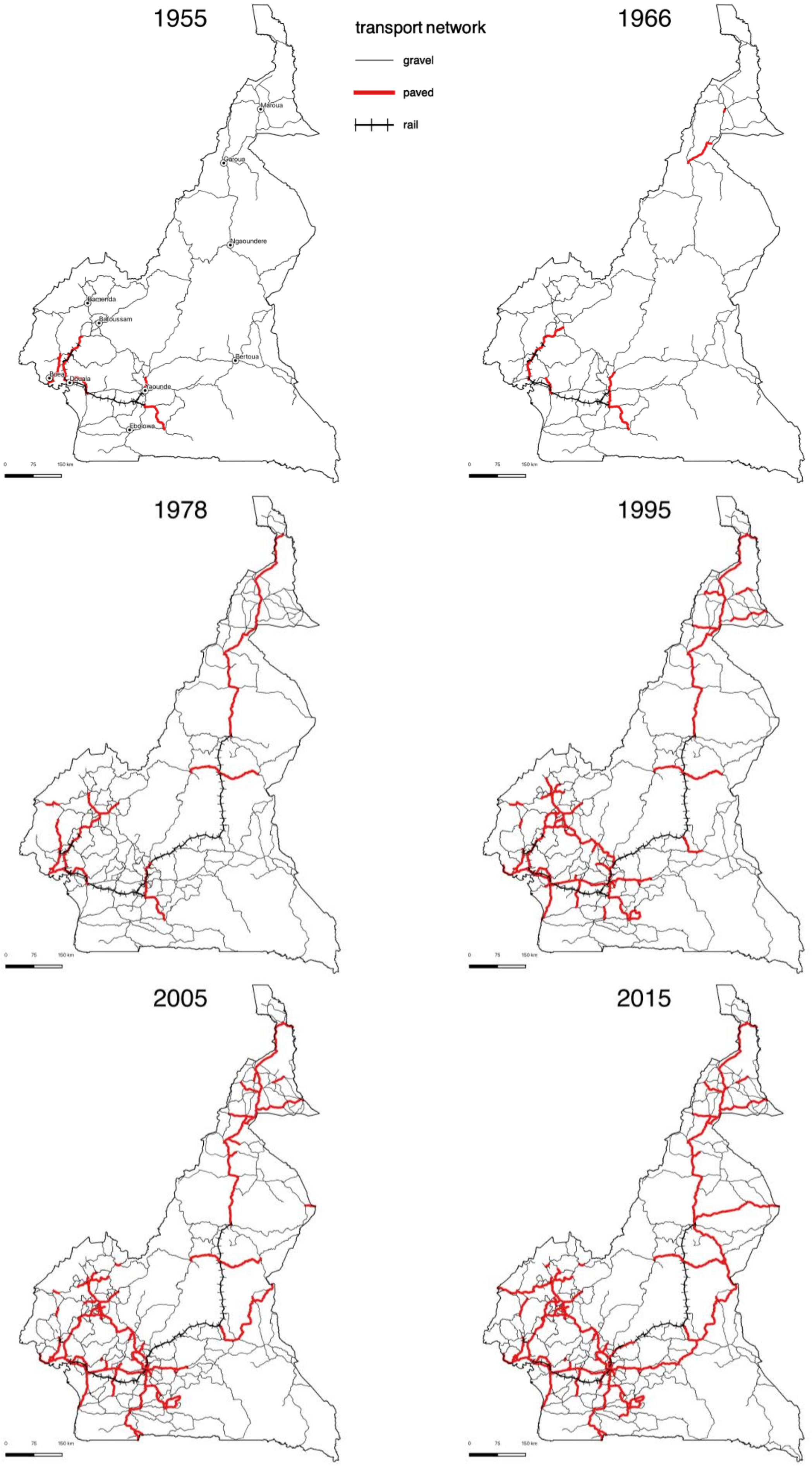


Figure 7.2. Paved roads in Cameroon in 1955, 1966, 1978, 1995, 2005 and 2015 (Source: Author)

As we have said on several occasions throughout this thesis, if we consider full connectedness as the one allowing quality trips on asphalted roads between all points of the transport network, then the network is still far from being a grid. In fact, we could say that, if we look only at the asphalted network and the rail, Cameroon would still be in the early stages of the Taaffe, Morrill and Gould model, probably still in stage D, the beginnings of interconnection. This is an important distinction. The fact that a road is asphalted has a significant impact on the quality of the service. Not only does it reduce vehicle operating costs, but it also means greater longevity of the same level of service, in particular under tropical weather. At the same time, a paved road requires a much larger investment and implies skills and significant funding to ensure that it lasts the time for which it was designed.

The meagre record in terms of asphalting the network is even more critical if we look at the growth of the number of vehicles in Cameroon. As we can notice in table 7.2 and figure 7.3, the number of vehicles licensed in Cameroon has an exponential progression.[103] In particular, from 1995, we observe a surge in the number of heavy vehicles above 3.5 tons for passengers and goods (buses, trucks, etc.), which have had more impact in the deterioration of the road. A paved network is particularly important for carrying heavy traffic. During the rains, truck traffic considerably deteriorates gravel roads. In Cameroon, long rainy seasons keep the roads constantly wet for weeks. In section 7.4, we will analyse in detail the increase of the heavy traffic and the consequences on the conditions of the road network.

	1930	1955	1966	1978	1995	2005	2015
Licensed vehicles (LV)	1,164	22,515	53,368	83,000	174,388	311,209	347,000
Annual growth LV (%)	NA	12.6%	8.2%	3.7%	4.5%	6.0%	1.1%
Heavy vehicles (HV)	685	9,681	15,630	19,000	23,389	42,215	63,323
Annual growth HV (%)	NA	11.2%	4.5%	1.6%	1.2%	6.1%	4.1%

Table 7.2. Evolution of the vehicle fleet in Cameroon. Licensed and heavy vehicles
(Source: Author based on historical sources and public statistics, notably from the International Organization of Motor Vehicle Manufacturers)

[103] These figures do not include motorcycles.

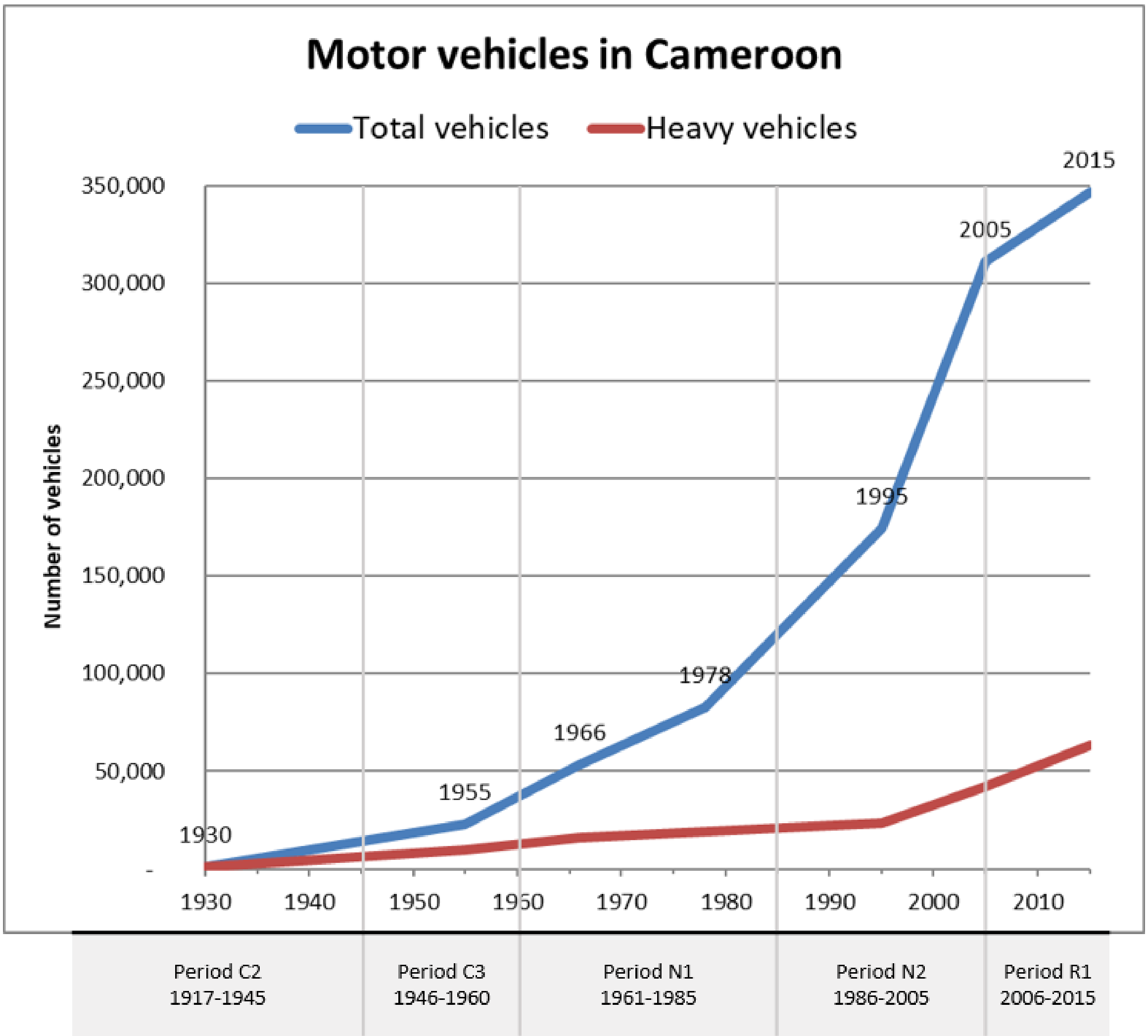


Figure 7.3. Evolution of motor vehicles in use in Cameroon 1930 – 2015 (Source: Author based on historical sources and public statistics, notably from the International Organization of Motor Vehicle Manufacturers)

In figure 7.4, we have compared the evolution of the fleet of heavy vehicles with the growth of the length of the paved network. The average annual growth of the period is indicated in red (heavy vehicles) and green (paved roads) in balloons. These two superimposed graphs have different scales on the Y-axis, and have years on the X-axis. Therefore, the slopes of the lines do not correspond to the percentage indicated. Nevertheless, some interesting conclusions can be drawn from this figure. From the mid-sixties, there has been an effort to increase the availability of paved roads, while the growth in the number of trucks remains low. However, from 1995, the average annual increase of paved roads stalls while heavy vehicles in the country burgeon at yearly increasing rates between 4 and 6%. This trend once again shows that, despite all efforts, the backlog in the development of the asphalt network has been increasing.

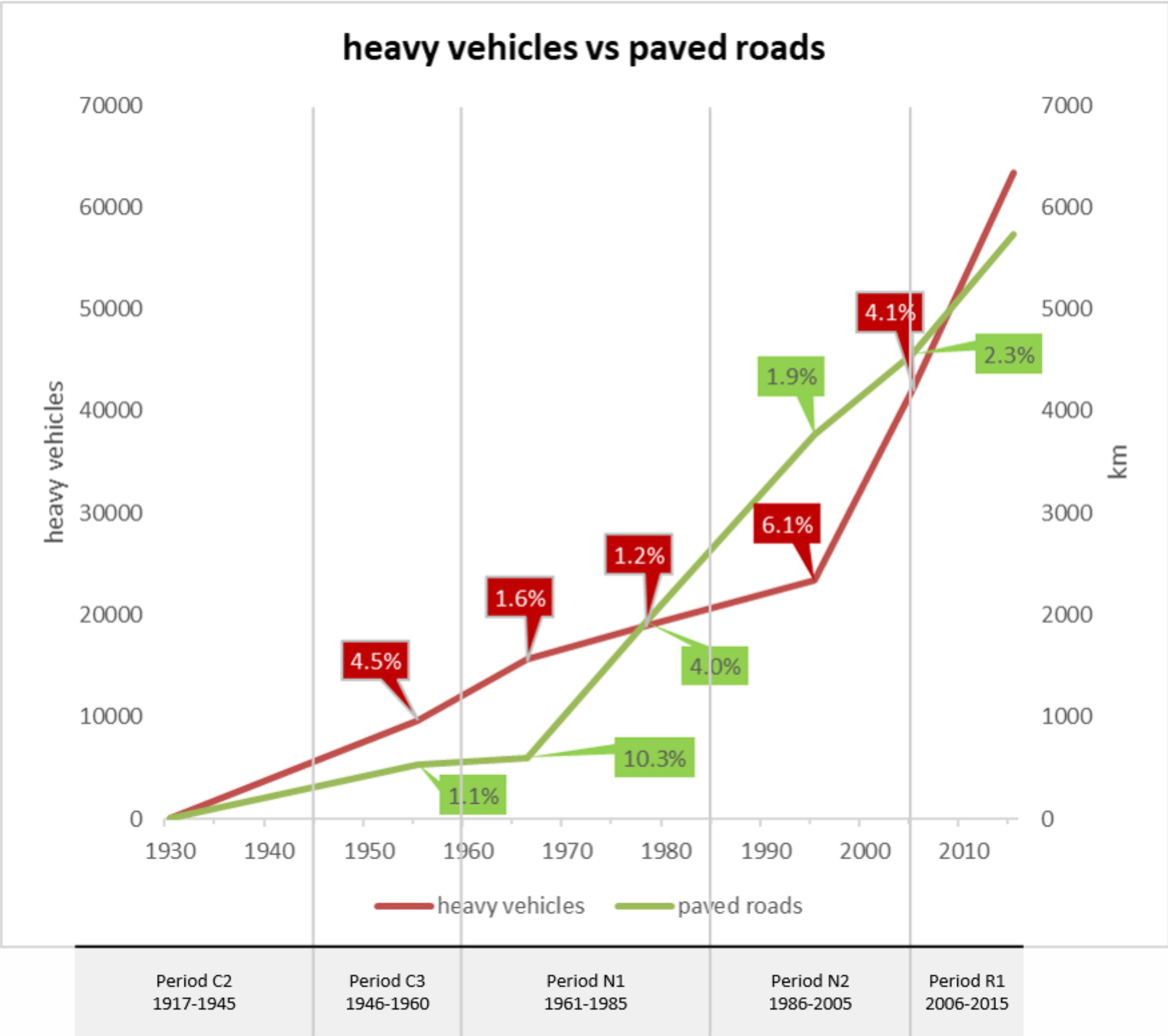


Figure 7.4. Evolution of heavy vehicles compared to the evolution of the paved network
(Source: Author)

7.2. Investment levels over time: an ever-increasing gap

Throughout the geohistorical review in chapter 4, in which we have summarised the main historical events and policies that have marked the evolution of transport infrastructure in Cameroon, the question of the high cost of paving roads and their subsequent maintenance, has been raised. To understand better the reasons that have hindered the extension of the paved network, we analyse more in detail the levels of expenditure in transport infrastructure over time in relation to the resources available.

To analyse the different levels of spending on transportation infrastructure in relation to existing resources in Cameroon, we have identified three intervals that roughly correspond to the moments in which there has been the greatest growth in the network. The first two intervals comprise 40-45 years of infrastructure growth (1884-1930 and 1945-1983) that, as we have seen, were respectively followed by 15-20 years of stagnation (1931-1944 and 1986-2005). The methodology to obtain the financial data in which these calculations are made is detailed in section 3.2.5. Results have been summarised in table 7.3 and represented in figure 7.5:

Period	Years	Amount spent (constant 2018 million €)	Amount spent/year (constant 2018 million €)	Average population (million)	Amount spent/year·capita (constant 2018 €)	Average yearly tax revenue (constant 2018 million €)	Average yearly tax revenue per capita (constant 2018 €)	Ratio spending/ tax revenue per capita
1884 1930	46	569	12	2.5	5.0	23	9.2	**54%**
1945 1985	40	7,050	176	4.8	36.9	391	85.3	**43%**
2006 2018	12	3,745	312	27.2	11.5	3,550	151.8	**8%**

Table 7.3. Transport infrastructure spending in Cameroon over different historical periods. [104] (Source: Author)

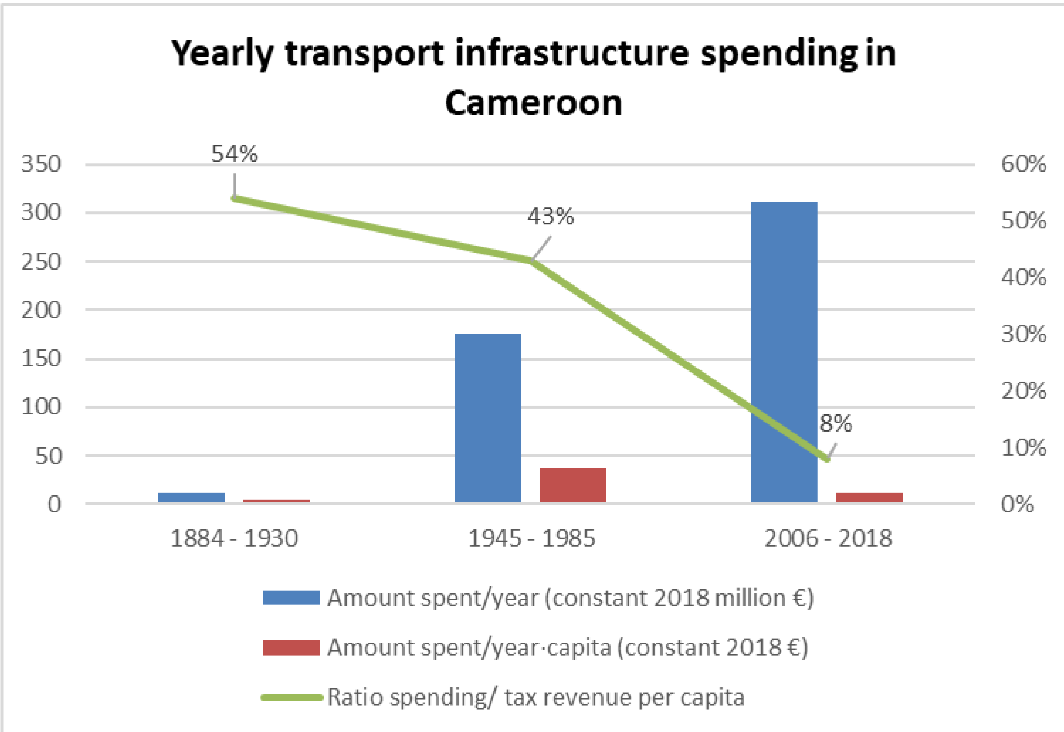


Figure 7.5. Evolution of the transport infrastructure spending per year in Cameroon (Source: Author)

[104] It includes all modes (airports, ports and inland waterways, road and railways)

Taking into consideration the historical analysis conducted in previous sections, we can draw several conclusions from this table and figure:

- In the early colonial period 1884-1929, tax revenue was low and investments in the transport sector comparatively significant. In a modern economy, it would mean that almost 54% of the national budget is allocated to infrastructure development. In this situation, grants from the metropole were necessary, but more importantly, the role of the private sector in railway development was crucial, as costs were recovered directly from tariffs on users.

- From 1945 to 1985, transport spending rose again to levels above 40% of the public revenues. These volumes are understandable in view of the political objectives of the last colonial years and the aim to enhance basic functions in the new independent country. However, in contrast with the period before 1929, where the private sector played an important role, infrastructure is developed essentially with public funds, both from the national budget and international aid.

- In the most recent years, spending levels in the transport sector are low in relation to tax revenues. The per capita ratio of yearly investment to public revenue is just 8%. Cameroon is far from the levels of previous periods. A priori, this could mean that the country still has room to contribute with public resources to the transport sector. However, as we can see in table 7.3, the average yearly spending in the transport sector is € 3.75 billion, while the total tax revenue is € 3.55 billion. It could be said that, only in the transport sector, the country already spends all the money that it collects from its citizens. The difference has to come from other resources like oil exports and issuing debt. According to the Directorate General of Budget, the loans for transport projects signed during the period 2010-2019 amount to € 3.7 billion. Consequently, as we have seen regarding the country's macroeconomic situation, further borrowing capacity is limited and spending in transport investments is not expected to increase sharply.

This last conclusion calls for a more in-depth economic analysis. The Cameroon of 2020 is very different from the one of 1920 or 1960. Since 1960, the GDP has multiplied by 8 and the population by 5 (figure 7.6). Hence, public revenues are higher but also spending needs, in particular, in sectors like education due to the age of the population (in 2019, 42% of the population was under 14 years old[105]).

[105] https://data.worldbank.org/indicator/SP.POP.0014.TO.ZS?locations=CM

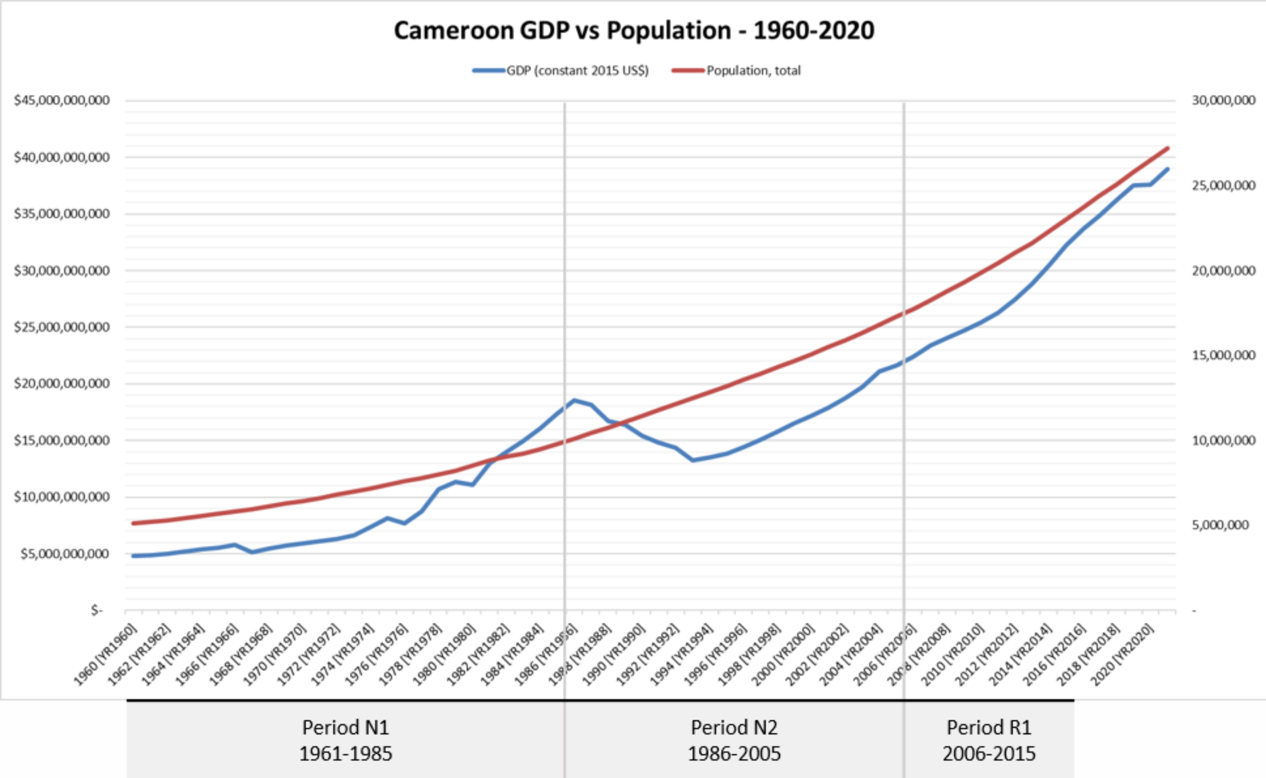


Figure 7.6. Evolution of the constant GDP and the population in Cameroon in the period 1960-2020 (Source: World Bank)[106]

As Cameroon is already struggling with debt management, it seems unlikely that the transport sector will be able to mobilise many additional resources. At the same time, transport demand is increasing as well as the need for additional investments to accompany economic development. The investment needs for the road sector estimated by the 2005 Road Master Plan, including maintenance, rehabilitation and overlaying were:

2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
373.5	391.8	411.6	431.4	451.2	471.1	492.4	515.3	536.6	559.5

Table 7.4. Road investment needs estimated by the 2005 Road Master Plan for the decade 2006-2015, in million €

Comparing tables 7.3 and 7.4, we observe that the actual spending in transport infrastructure in all modes was 312 million € per year for the period 2006-2018 while, only for the road sector, investment needs were estimated from 373.5 million € in 2006 to 559.5 million in 2015. The Road Master Plan in 2005 had already noticed the

[106] https://databank.worldbank.org/reports.aspx?source=2&series=NY.GDP.MKTP.KD&country=CMR#

inadequacy of the financial resources when looking at the options to finance the different scenarios it was proposing.

We conclude that, in the last studied period 2006-2018, Cameroon is far from the investment levels of the past while demand is increasing and there are still significant needs for transport infrastructure expansion. Given this situation, the question that arises is whether, on the basis that resources are insufficient and competing with other development priorities, the investment decisions could have been better made. In addition to quantity, there is a need to look at the quality of investments and whether they optimise the use of scarce resources. However, as we have seen in the preceding chapters, which examined the efficiency of investments along the different periods according to their spatial impact, the choice of the most economically viable investments has not always been the case.

7.3. The heavy burden imposed by road maintenance

In figure 7.1, the flattening of the purple line (total transport network) indicates that, from 1978, the overall network was reaching its maximum connectedness. The red line and the blue line correspond respectively to the gravel and paved roads. As the total network is not growing much, if the asphalting policies were succeeding, these two lines should have been progressively closer, or even cross each other at some point. However, they have remained almost parallel, and it is only from 2005, that the gap starts to get narrower. The reason is that weak progression of the asphalted network is worsened by the lack of adequate maintenance and truck overloading, as Harral and Faiz signified already in 1988 for Sub-Saharan African countries. Contrary to what we have indicated in relation to the perenity of the road network, the paved network can shrink. Lack of maintenance can bring some links back to gravel standards. Overall, the length of paved roads in Cameroon have always been growing but, over the years, some links deteriorated to an extent that they were not considered as asphalt roads anymore. Consequently, the expansion of the paved network has decelerated. While new roads were constructed or upgraded, others were irremediably ruined because of poor maintenance.

As we have seen in the analysis of the different periods, the problem of road maintenance is not only recurrent, but also increasing. The greater the infrastructure provision, the greater the need for maintenance. In addition, as we will see in the following chapter, an appropriate axle-load control is fundamental to protect the roads and, consequently, to preserve their design lifespan. The vicious circle of lack of maintenance, poor road conditions, lower road productivity, increased spending needs and reduced revenues for road management is difficult to break and leads to an exacerbating problem: if roads are in bad condition, truck operators perform less trips and are less incentivised to renew their fleets, thus are more inclined to overload. If this situation of poor maintenance and truck overloading worsens, it ultimately results in the disappearance of some paved sections, or rather their return to gravel conditions. We can see this happening several times when comparing two successive maps of figure 7.2.[107]

For the last two decades, it is interesting to take a closer look at the official data provided by the Road Fund in its annual reports. In figure 7.7, we have represented the budget allocated to the Road Fund and the funds committed for road maintenance works contracts since 1998. The minimum in 2002 is explained by the fact that, in that year, the budget was adjusted to correspond with the natural year and therefore the amount corresponds to 6 months only. Besides this valley, the chart has other noticeable features. Between 2010 and 2014, the budget allocated to the Road Fund was limited to a maximum of CFA Francs 55 billion. From then, the ceiling was CFA Francs 60 billion, but we observe that it was still not fully used. Several factors explain this under consumption. Firstly, the introduction, from 2011, of multi-year contracts and other efficiency improvements sought over the medium- and long-term but that slowed down the procurement processes in the short-term due to inadequate capacities. Secondly, in 2013, the reform of the public procurement system at national level had a major impact in awarding contracts for road safety. Finally, this irregular performance should be found in the lack of absorption capacity on the side of small and medium enterprises in the road works sector in Cameroon. This is the explanation behind the minimum reached in 2015. In that year, according to the Road Fund annual report, the Ministry of Public Works decided to slow down the awarding of new contracts because there were too many defaulting ones under execution. Instead, the Ministry decided to focus on terminating old contracts with largely expired execution deadlines.

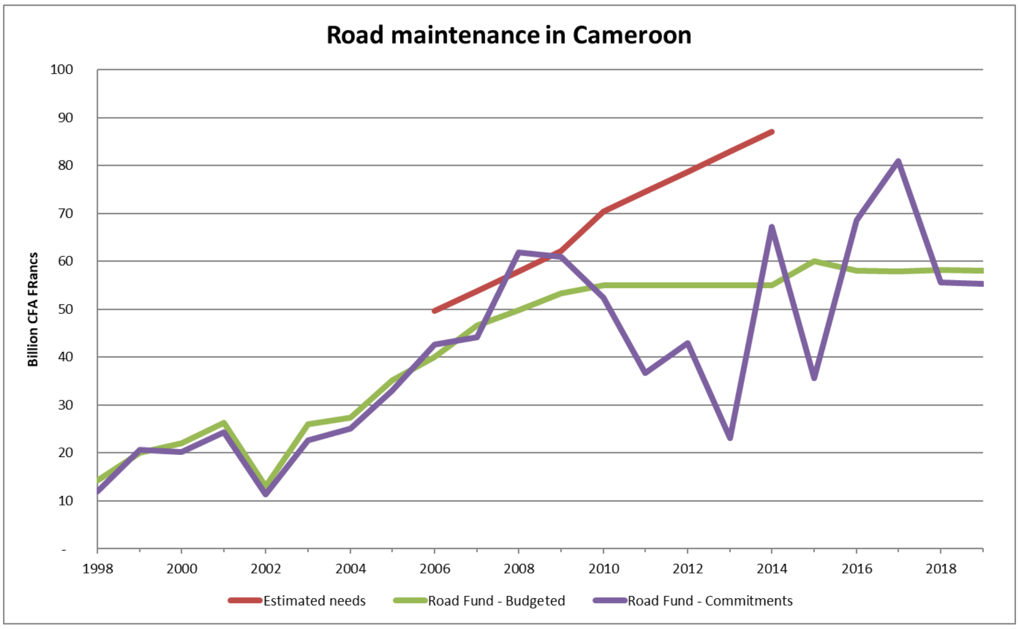


Figure 7.7. Allocations to road maintenance in Cameroon in the period 1998-2019
(Source: Author based on Road Fund data)

[107] See, for instance, the road D16, close to Garoua, from Pitoa to Adoumré. This road was once considered as paved.

The red line in figure 7.7 indicates the estimated need for road maintenance according to the Road Master Plan elaborated in 2005. The trend clearly shows a divergence between needs and allocated and committed funds. However, as we have just explained, an increase of the Road Fund operating budget would not solve the problem if there were not enough contracts awarded and contractors capable to perform the works according to the quality standards and contractual duration. In fact, the ceiling of CFA Francs 55 million, first, and then, of CFA Francs 60 billion, originated from the fact that the Road Fund accumulated an extraordinary amount of dormant funds and the Ministry of Finance, faced with treasury tensions elsewhere, decided to cap the allocations for road maintenance.

In conclusion, it is not just that the road sector in Cameroon is underfunded as we have seen in the previous section, but also that the lack of adequate maintenance may be slowing down the progress in enlarging the paved network or even reversing the conditions of some roads from asphalt to gravel surface. Unfortunately, in most of the years for which the network has been mapped, the conditions of the roads were not extensively known or not well documented in the official sources of information. It is only after 1995 that the Ministry of Public Works started to survey road conditions and compile this information in a road database. This data is vitally important to characterise the network, as we have seen in the previous chapters.

7.4. Road asset management: cost-effectiveness of axle-load regulations

Beyond the reflection about where to prioritise new investments, the issue of road asset management remains critical. As we have seen in the previous chapters, roads are not protected enough, and maintenance fails. Therefore, this chapter is completed with the study of the "high-priority main streets'', as Taaffe, Morrill and Gould designated in 1963, and which are now known as transport corridors. Although relevant transport corridors will necessarily continue to absorb a significant part of the investments, it is important to ensure that they do not unnecessarily drain the budgets allocated to transport infrastructure because they are now well maintained.

While truck overloading and lack of maintenance are problems that happen in the entire network, zooming into a specific major corridor is an adequate approach. Therefore, this part of the research focuses on the study of vehicle load management along the corridor between Douala and N'Djamena, Cameroon's busiest route, and key to the development of Chad and the Central African Republic. We have chosen this corridor because, since 1998, detailed truck loading control data has been collected at nine stations along the corridor (figure 7.8). Given that they are still operational, and, at first sight, their purpose seems to yield good results, the available data is a valuable source of information worth studying.

Figure 7.8. The nine consolidated sections in the Douala – N'Djamena corridor used in the paper (Source: Torres Martínez, Oliete Josa, Magrinyà & Gauthier, 2018)

The methodological basis for this study can be found in section 3.2.7 and the details as well as the appendices with the data are published in our paper: *Cost-effectiveness of enforcing axle-load regulations: The Douala-N'Djamena corridor in Sub-Saharan Africa* (Torres Martínez, Oliete Josa, Magrinyà & Gauthier, 2018)[108]. The article begins by describing the causes and consequences of truck overloading in Sub-Saharan Africa. A

[108] https://www.sciencedirect.com/science/article/pii/S0965856416311946

problem that has been identified for decades but is difficult to solve due to a fragile institutional context. We have noticed that despite numerous reports analysing the situation, there is little work aimed at quantifying the problem economically. We therefore analyse the case of Cameroon, where the progressive application of axle-load control regulations has produced appreciable benefits, although there are still significant shortcomings.

The research methodology is based on the HDM model and the load equivalency concept. HDM simulates the behaviour of roads throughout their life cycle taking into account the effect of traffic. The HDM 4 model has been applied to three scenarios between 2000 and 2015: (1) no axle-load control, (2) the real situation and (3) no overloading tolerance. The paper also explains why, for the calculations of the load equivalency factors (LEFs), it is preferable to use the Equivalent Single Axle-Load (ESALs) equations, derived from the AASHO Road Test, rather than the more commonly known simplified fourth power ESAL formula.

Figure 7.9 shows the research process that has been followed in the paper. First, ESALs, LEFs and average weights are estimated per vehicle type, weighing station and year selected for analysis. These intermediary results feed the HDM-4 road deterioration model (RDM) and road user costs model (RUC). These models are run for all the overloading control scenarios, road sections and time periods. The results obtained are vehicle operating costs, travel time costs and estimation of the periodic maintenance and rehabilitation backlog. Finally, cost-effectiveness ratios of axle-load control are estimated for the overloading control scenarios.

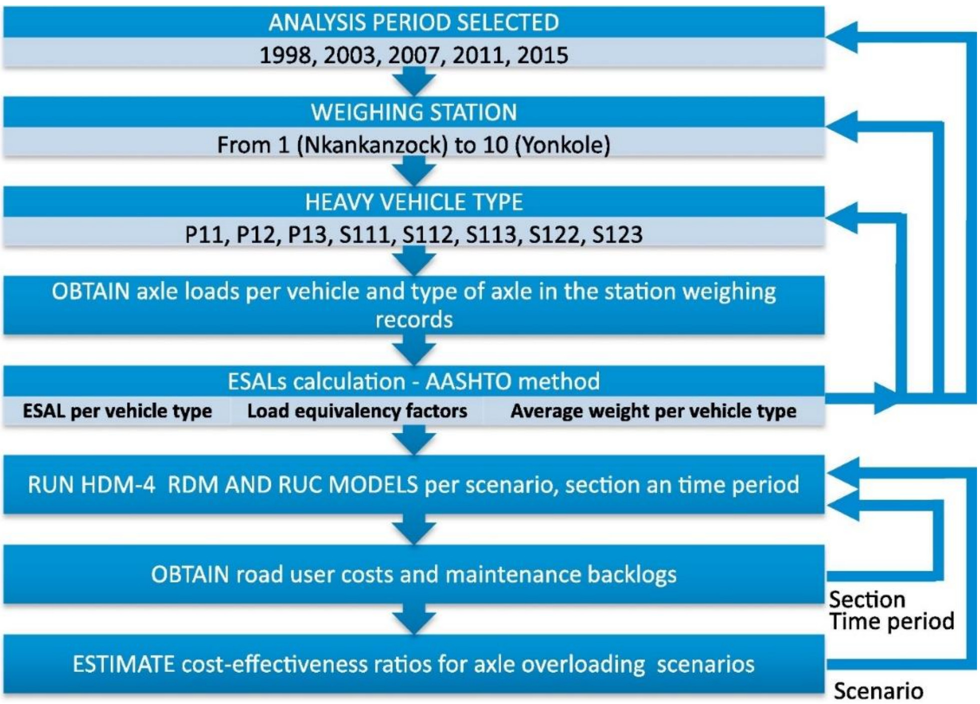


Figure 7.9. Methodology used to estimate the cost-effectiveness of enforcing axle-load control (Source: Torres Martínez, Oliete Josa, Magrinyà & Gauthier, 2018)

The paper concludes that, in the Douala-N'Djamena international corridor, every € invested or spent in axle-load control duly enforced by the authorities in 2000–2015 has generated €19.4 savings in road user costs and €4.6 savings in road maintenance and rehabilitation expenditure. It means that, in absolute terms, only in one itinerary, the government has saved more than € 500 million in fifteen years, which is € 33 million per year. If, as we have seen in section 7.2, between 2006 and 2018, Cameroon spent on transport infrastructure about 312 million € per year, the savings generated by protecting the road against overloading are significant.

Despite these encouraging conclusions, the article also identifies a logical but worrying trend: despite the significant reduction in truck overloading, the increase in heavy-duty vehicles traffic over the last few years is counteracting the gains made. This tendency can be seen in figure 7.10 where we have depicted the evolution of annual estimated equivalent 13-ton axle loads per vehicle type in the Edéa-Yaoundé section.

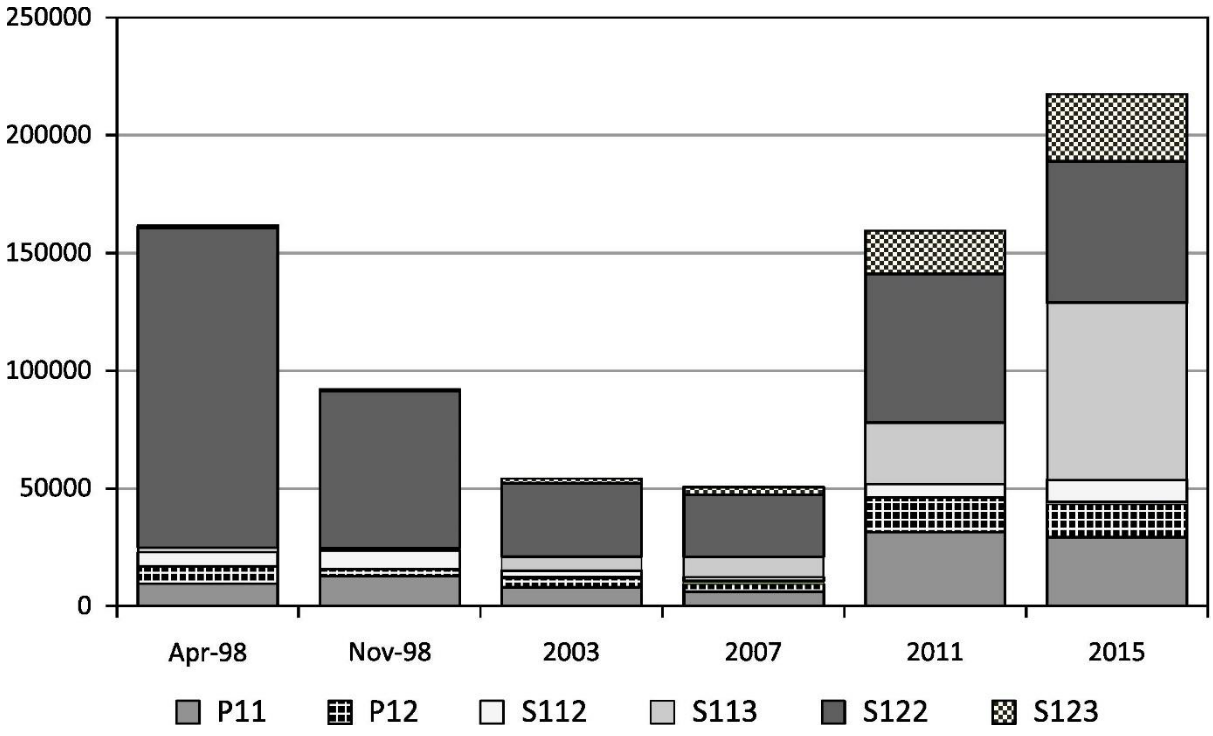


Figure 7.10. Evolution of annual estimated equivalent 13-ton axle loads per vehicle type, Edéa-Yaoundé road section. [109] (Source: Torres Martínez, Oliete Josa, Magrinyà & Gauthier, 2018)

If Cameroon is not able to expand or improve its connectivity in the coming years, at least the network should not contract. As traffic increases, axle-load control should not allow tolerances and exceptions. Even the limit of 13 tons per single-axle and 50 tons for gross vehicle weight should be reduced to bring it into line with international practice, which is usually 10 and 40 tons respectively. To achieve this, as explained in the article, effective

[109] Rigid vehicles: P11: 2 single axles, P12: single-tandem, P13: single-triple. Articulated vehicles: S111, S112, S113, S122, S123)

action against vehicle overloading cannot be limited to the installation and operation of weighing stations. It must be extended to all trucking industries, especially transport companies, shippers, and logistic operators. A broad set of actions are also needed to tackle the problem at the regional level and at different subsector levels (transport liberalisation, port operation reforms and coordinated regional actions) because fighting overloading in some countries and corridors and not in the others may cause distortions in competition and traffic diversions.

7.5. Present and prospects of the transport network in Cameroon

As we have explained in section 4.2.5, in December 2014, President Paul Biya announced the implementation of the three-year Emergency Plan 2015-2017 for the acceleration of economic growth. The plan was financed by loans contracted by the State from a local banking pool and international financial institutions, mobilising about CFA francs 566 billion (€ 861 million) for the implementation. These investments were in addition to the large-infrastructure projects already started as programmed in the 2010 *Document Stratégique de Croissance et d'Emploi* (DSCE). Apart from the fact that this initiative was taken in a context of worryingly rising debt, one remarkable aspect of this plan is what it envisages in terms of road infrastructure. It aimed at paving two roads per region, allocating approximately the same amount to each region and the same number of kilometres. We interpret this decision as an absence of a demand-driven transport policy, but on the contrary, the government, being overwhelmed by the inability to respond to the growing mobility needs, chooses to share the investments equally among all regions. It is a clear manifestation of the preponderance of the surface area factor in decision-making, to the detriment of the weight of the population.

In 2017, the road classification was changed to align it with the administrative territorial division provided for by the constitution: regions and *communes*. This is a major reform, because, from that moment on, the Ministry of Public Works was no longer in charge of all the roads. Although it retained overall supervision of the network, its responsibility was limited to the management of motorways and national roads. On paper, the regions managed regional roads and the *communes* managed local or *communal* roads. The roads analysed in this research, which in 2015 were approximately 21,164 km, correspond approximately in 2017 to the addition of national and regional roads, which total 23,293 km. According to the Ministry of Public Works figures,[110] in 2020, only 49% of national roads (table 7.5) and less than 7.5% of regional roads were asphalted. These figures do not include urban roads as they count as *communal* roads.

[110] http://www.mintp.cm/fr/projets-realisations/presentation-du-reseau-routier consulted on 23 January 2022

	paved roads	% paved	gravel roads	total
Adamaoua	615	45%	764	1,379
Centre	756	65%	412	1,168
Est	466	81%	108	574
Extreme-Nord	563	32%	1,179	1,742
Littoral	332	99%	3	335
Nord	543	51%	517	1,060
Nord-Ouest	200	40%	302	502
Ouest	304	92%	26	330
Sud	474	34%	901	1,375
Sud-Ouest	317	35%	588	905
TOTAL	4,570	49%	4,800	9,370

Table 7.5. Distribution of national roads by region and by type of pavement in 2020 (Source: Ministry of Public Works, Cameroon)

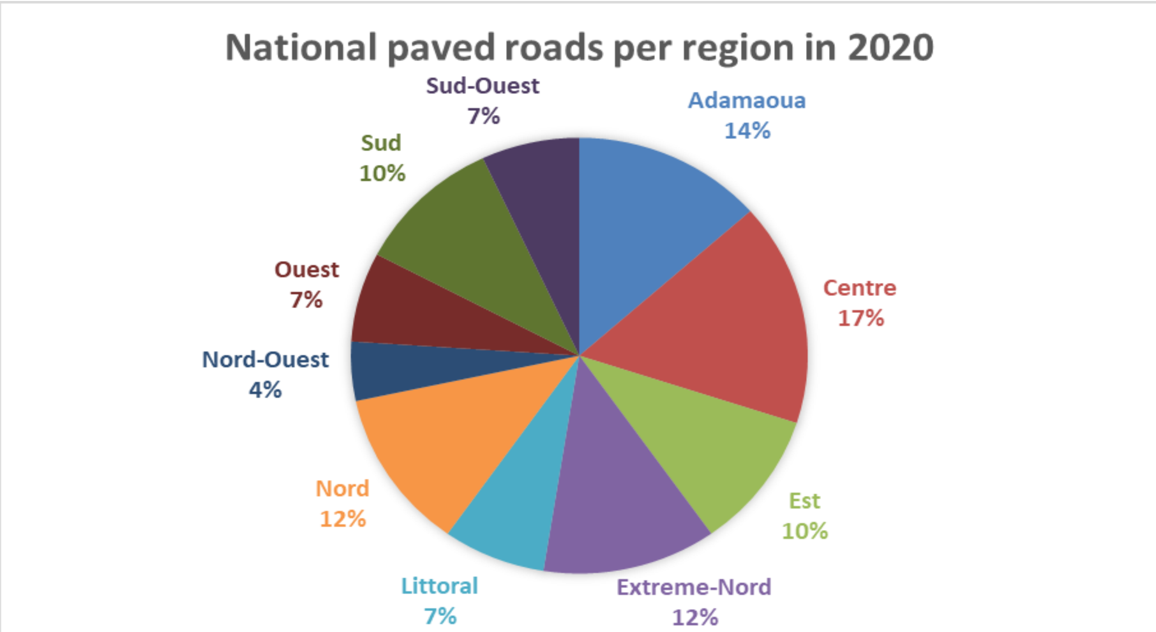


Figure 7.11. Distribution of national paved roads by region in 2020 (Source: Ministry of Public Works, Cameroon)

We note in table 7.5 that the dispersion of the length of national paved roads[111] is much lower than the dispersion of the total length of the roads.[112] This tendency towards homogeneity of the length of the paved roads can be observed in figure 7.11. We also note

[111] Mean = 457; Standard deviation= 160.64; Interquartile range: 246

[112] Mean = 937: Standard deviation= 464.39: Interquartile range: 873

that two of the most densely populated regions, the Ouest and the Littoral, have almost all their national roads paved while the two other most densely populated ones, the Extreme-Nord and the Nord-Ouest, have less than 40% of them. At the same time, the Est, a region with a low population, has one of the highest percentages of national roads paved. This is another example of a mismatch between where people live and where investments are made. It confirms a continuity of the infrastructure-planning trend that gives more importance to the surface coverage than to the population.

Since 2015, Cameroon has started and, in some cases, completed, the construction, asphalting or rehabilitation of several national roads and highways that would certainly have had an impact on the calculations made in this research. To name a few of them:

- National road No 1, Maroua-Kousseri, 266 km
- National road No 2, Nsimalen-Ebolowa, 138 km
- National road No 4, Yaoundé-Bafoussam, 196 km
- National road No 6, Bafoussam-Bamenda, 97 km; Foumban-Magba, 66 km
- National road No 8, Kumba-Mamfe, 151 km
- National road No 9, Sangmelima-Djoum-Mintom-Mbalam, 322 km
- National road No 15, Batchenga-Ntui-Yoko-Tibati-Ngaoundéré, 593 km
- National road No 22, Olama-Kribi, 204 km
- Highway Yaoundé-Douala (1st phase), 69 km

In addition to this selection of the most notable projects, more than 1000 km of regional roads have been asphalted since 2015, in most cases with low-cost paving. We also note a few costly projects to improve the accesses to Douala and Yaoundé, by adding more road capacity: the east and west access roads of Douala, the second bridge over the Wouri River in Douala and the Nsimalen Airport-Yaoundé highway.

7.6. Conclusions of the investment analysis: too late for the “big push”? The importance of asset preservation

As we have seen throughout the preceding sections, in past growth periods of the transport network, first, during the colonisation (period C2) and, then, in the years immediately after the independence (period N1), investments in transport infrastructure in relation to the total public revenues were higher than in the 2000s. Nowadays, the path towards development implies significant expenses, notably social (education, health, waste management, etc.), which were not considered so important in the past. Competing policies and investment priorities mean that funding for the transport sector is no longer as dominant. In addition, coupled with population growth and rapid urbanisation, the demand for mobility and freight transport has significantly increased, and will continue to grow. Therefore, over time, spending needs in transport have increased, in terms of not only new infrastructure but also regarding maintenance and more intensive use due to the growth of heavy-duty vehicles. This situation reduces the government's capacity to manage and extend transport services. Therefore, in Cameroon, the transport infrastructure gap is increasing, and the trend seems difficult to reverse.

We have seen that, undeniably, the golden era of the Cameroonian transport infrastructure started in the mid-1950s (end of period C3) and ended in the late 1970s (period N1). Prior to that, there had been another key period of expansion around the 1920s between the two World Wars (period C2). A reasonable question to ask is whether, during these past periods of investment, governing regimes and international donors should not have been more ambitious and gone further in the provision of transport infrastructure. This observation leads us to recall the "big push" theories popularised at the end of the 1950s by influential economists like W. Rostow and Rosenstein-Rodan. Although these theories were also heavily criticised on the grounds that low-income countries lacked of skilled human resources and institutional capacity to absorb large amounts of foreign aid (Adler, 1965; Myint, 1969), the reality is that countries like Cameroon, where investments were substantial in the past, have not been able to catch up in terms of transport infrastructure. Now, as we have seen, a "big push" seems unlikely in view of the budgetary constraints, with many needs to be met and the difficulty of covering maintenance costs. Therefore, while there is little reason for optimism about an extension of the network to meet the growing demand for mobility, authorities' efforts to protect the network and extend their lifespan show the way forward. The scarce funds should not be dissipated in rehabilitating infrastructure that has deteriorated prematurely.

8. General conclusions

8.1. Summary of findings: the long road from aspirations to reality

The purpose of this PhD thesis is to contribute to the improvement of transport policies in Africa. To this end, we have chosen to study the decision-making processes that have affected the development and maintenance of transport networks in Sub-Saharan Africa since the colonial era, focusing on the case of Cameroon. We have asked what the efficiency of the network has been over time, which we define as the convergence between the implemented and the maximum network. From the state of the art, we have concluded that, drawing from different disciplines, it is possible to characterise the evolution of the network over time by quantifying how it diverges from the maximum theoretical one and relating it to the power strategies.

The focus on the discrepancy between the maximum and the actual network has led us to question the status of the notion of "infrastructure gap", which has existed since the 1970s but has become popular in the last decade following the adoption of the Addis Ababa Action Agenda in 2015. The literature review allows us to follow and expand, for the case of a Sub-Saharan African country like Cameroon, the postulates of transport geography and the evolutionary network logics of transport infrastructures. Network analysis is gaining new dynamism with development studies in countries such as China and India, which are in an expansive phase in network construction (Jin *et al.*, 2010, Jiao *et al.*, 2014, Daniel, Saravanan & Mathew, 2020; Daniel, Mathew & Saravanan, 2021). We are interested in taking up this new momentum of transport geography in the case of Central Africa, and specifically in Cameroon. We have looked at an approach that blends network analysis through new computer tools and a transdisciplinary approach to geohistorical analysis. This research deepens and develops on the Taaffe, Morrill & Gould model of the evolution of transport networks in developing countries (Taaffe, Morrill & Gould, 1963), on Raffestin's geographical works relating networks and power (Raffestin, 1980) and on Debrie's application of Raffestin's theories in the case of West Africa (Debrie, 2010).

Raffestin defines the maximum network as the one that allows direct connection between all nodes as if there were no impediment of any kind. This does not happen in the real world because resources are finite and, in reality, we never deal with the maximum network, but with one that "is a compromise between the maximum network, available resources and real conditions" (Raffestin, 1980). This is the reason why in this thesis we refer to network *efficiency* and not network *effectiveness* to refer to the convergence between the maximum network and the actual one. Thus, we look at the functionality of the network considering the available resources, the political will, and the capacity to implement it. We have evaluated, for the case of Cameroon and at different points in time, the characteristics of the road and rail network and assessed how it corresponds to the social and economic needs of each historical moment.

To operationalise our research, we have set out four specific hypotheses that stem from the general hypothesis. The first is that there is a characterisation of the transport network growth and stagnation cycles defined by the different political regimes and colonial relationship periods. We anticipated that it is possible to base the differentiation between these periods on how the network expands or stagnates and that it is possible to quantify the level of network formation in each period. For this purpose, chapters 4 and 5 have consisted of a geohistorical review of the evolution of transport links in Cameroon combined with a topological analysis based on classical indicators of quantitative geography. This work has made it possible to identify **six different periods characterised by specific forms and rates of growth of the transport network**. In the same way, while determining the correspondence between the maximum and the implemented network, we have been able to associate these periods of network growth with the predominant political regime's strategy, the development paradigm, and the functionality of transport at the time.

The first colonial period (C1. 1884-1916), during the occupation by the German Empire, was a time of exploration of the different routes of penetration. The investments were modest, and the predominant strategy aimed at the financial autonomy of the colonies. In the second period, with the French and British mandate (C2. 1917-1945), in the inter-war period, the colonial administration was confronted with the need to prioritise certain routes of penetration. The selection criteria were not the population distribution (Douala-Foumban-Tibati route) but the territorial control (Douala-Yaoundé-Bertoua route). The third period corresponds to the end of the colonial occupation (C3. 1946-1960). Despite a significant increase in investment, it was only concentrated in the area closest to the coast, the most fertile, which is bounded by Yaoundé, Bamenda and Bafoussam. This policy reinforced rural-urban movements and was at the root of the impoverishment of the north.

The fourth period was the first national period (N1. 1961-1982). It was characterised by the pursuit of national unity through infrastructure, in particular the west English-speaking and north, both of which were connected by rail. This is the period of maximum growth of the network and when practically full connectedness was achieved (although not through asphalted roads). In the fifth period, the second national one (N2. 1983-2005), Cameroon went into recession and chronic economic crisis, which led to dependence on external financiers and a focus on paving roads to make the domestic economy viable. This policy and the structural adjustment programmes put great strain on the viability of the railway, which led to the closure of some unprofitable sections. In this period, the rural-urban and north-south migration trend was accentuated.

The sixth geohistorical period (R1. 2006-2015) was characterised as regional because of the great importance of international free trade and economic integration policies. Despite improved macroeconomic prospects, Cameroon remained highly dependent on foreign investments that prioritised interconnections with neighbouring countries. It was in this context that actors such as China, Turkey and Russia appeared, accelerating the agenda for the extraction of raw materials, with all the opportunities and challenges that this entailed.

In chapter 6, we have deployed the research tools allowing us to support the second specific hypothesis. We have found that in each geohistorical period, the transport network develops according to a predominant trend in the dialectic between networked economic development (population) and development by networked territorial control (surface). We have used network fractal theory to make an explicit correspondence between the spatial trends of network development and policy decisions. In this respect, we have **explained the provision of transport infrastructure in terms of both territorial and population distribution and linked it to the accessibility to the main cities**. For the analysis of accessibility, it is necessary to differentiate between asphalt and gravel roads, given that road conditions have a great influence on the quality of service and transport time. The conclusion is that in the last colonial period (C3. 1946-1960), the population significantly increased its weight as a decision criterion for transport investment. It was during the FIDES programme, which prioritised infrastructures in the "fertile crescent" near the coast. Conversely, during the national period, the population factor has been losing importance. Since then, the strategies of successive powers have consisted of distributing transport infrastructures evenly to obtain good territorial coverage, even if it has been far from the cities and this has meant building infrastructures with a lower cost-benefit ratio. This trend has been accentuated in the last regional period (R1) from 2005 to 2015.

In chapter 7, we have studied the **capacity to finance the expansion of the network and to maintain it**. The third hypothesis states that economic development undergoes regressions due to the prioritisation of nodes, routes, and territories, some of which are impoverished over time. The fourth hypothesis is a concrete manifestation of this evolution as we demonstrate that there is a hierarchical organisation of the network and that this discrepancy between the maximum and the actual executed infrastructure is the result of biased planning, funding decisions and the capacity to implement and maintain the network. The third and fourth hypotheses mutually reinforce each other and relate transversally to the first two hypotheses. We further show that, in the face of scarce resources, rising transport demand and a significant increase in social spending associated with population growth, it is not only necessary to make the right investment prioritisation decisions, but it is essential to protect the network from premature deterioration. In the paper Torres Martínez, Oliete Josa, Magrinyà & Gauthier (2018), we prove that enforcing axle-load control regulations for trucks is an appropriate and low-cost way to extend the life of investments.

Considering our findings, we can say that transport policies in Cameroon have facilitated a convergence between the maximum and the executed network, in the sense that they have favoured a grid pattern and have aimed for a complete territorial coverage. However, the asphalted network has a limited coverage and some routes prioritised involve major detours compared to the more direct connections and favour the accessibility of only some of the cities such as Yaoundé and Bertoua. We have demonstrated that the relative weight of transport infrastructure budgets in Cameroon is declining while demand is increasing, and roads do not last as long as they were designed for. Therefore, Cameroon cannot afford to asphalt extensively its entire territory. Consequently, there is a hierarchical structuring of the transport network, which is materialised in the prioritisation of the paving of certain roads of the main network. In a context of macroeconomic constraints, the implementation of transport policies has clear consequences for the distribution of the socio-economic development of the population. Certain nodes and territories are impoverished because they do not benefit from the prioritised routes. The government has opted for territorial equity rather than concentrating on providing access and fluidity to the main metropolitan areas, where the population lives and there are higher social and economic returns.

8.2. Timeline of the evolution of the transport network in Cameroon

As explained in chapter 4, the starting point for the part of the research related to the first specific hypothesis is the timeline we proposed in 2018 describing the evolution of transport networks in Sub-Saharan Africa, which was a development of the model of Taaffe, Morrill & Gould outlined in 1963 (Oliete Josa and Magrinya, 2018). The case of Cameroon reaches a level of detail that was not achieved in our paper. We have been able to quantify the speed of network expansion, linking it to the political regime and determining with relative accuracy when expansion has been most intense and when it has slowed down. The delimitation of these periods confirms the expansion-stagnation cycles anticipated in 2018 and allows us to improve and complete the timeline and summarise the most relevant findings of this thesis.

Figure 8.1 is an adaptation and improvement of figure 4.2. We have replaced the rows on major international events and policy documents by a row reflecting the changes of political regime and a row showing the major events affecting the country. For reasons of space, we have deleted the ones relating to the external policy influence and on the negative effects of the transport policies. Instead, at the bottom of the table, we have added an adjusted sequence showing the three cycles of the network development, together with quantitative data selected from the results obtained in this research. In different green shades, we have indicated the average annual growth of the length of the network, including gravel and paved roads and the railway. The lighter green shows the lowest growth values, while the darkest indicates the years where the network has experienced the highest expansion. Using different shades of blue, we have represented the average annual growth of the paved road network only. Finally, with brownish oranges, we have indicated the connectivity indicator GTP (grid-tree-proportion index). Finally, we have replaced the Taaffe, Morrill and Gould phases by the Cameroon spatiotemporal transport network outlines that we defined in chapter 4.

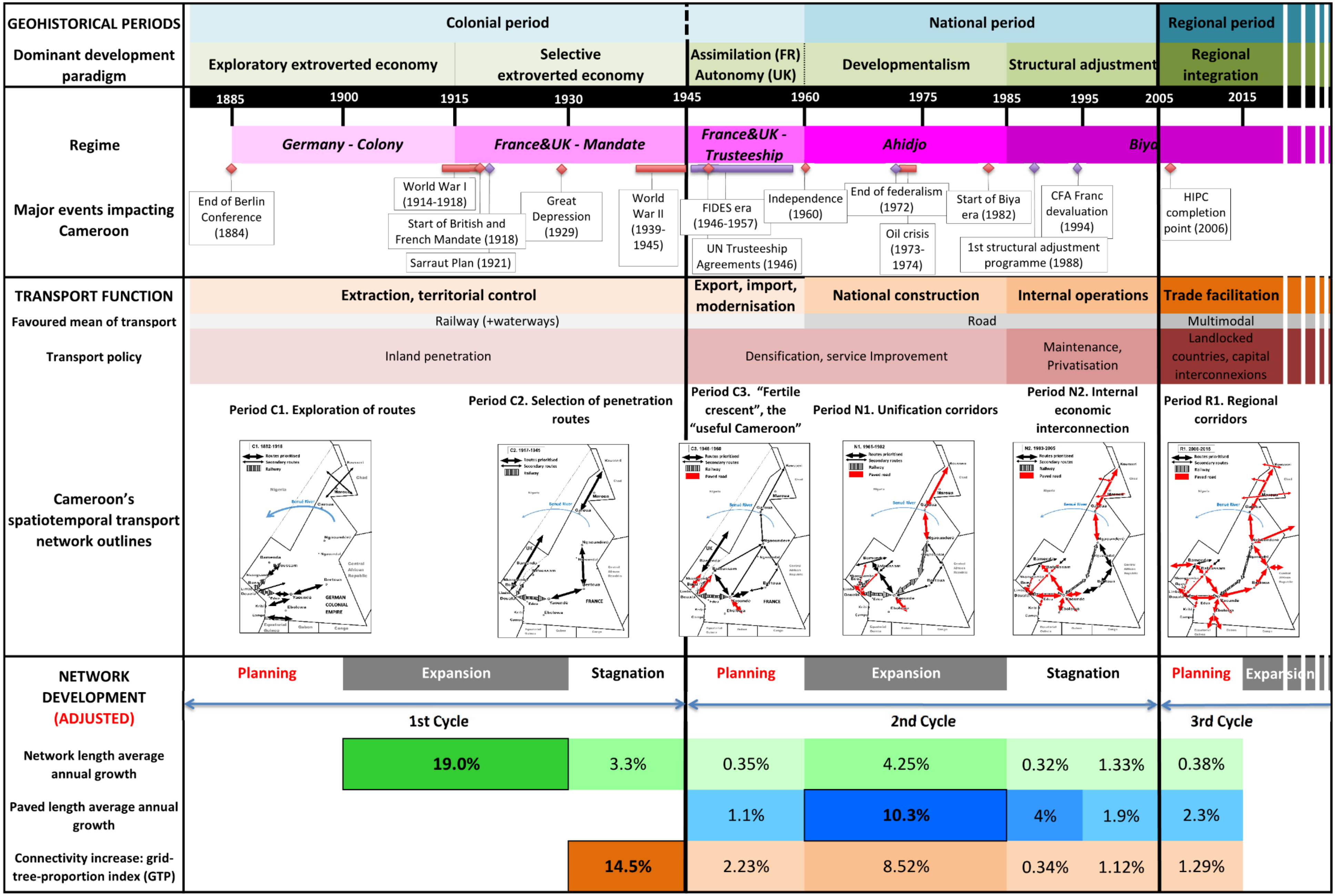


Figure 8.1. Timeline of the evolution of the transport networks in Sub-Saharan adjusted to the case of Cameroon (Source: Author)

Regarding the evolution of connectivity, it is difficult to draw conclusions from the quantitative data available for the colonial periods C1 and C2, as there were few asphalted roads and the network was still very fragmented, hence the connectivity indicators cannot be established. Yet, in figure 8.1, for the first cycle of network development, we can confirm the slowing down of the network growth during the stagnation phase (3.3% of average annual growth). Paradoxically, at the same time, we observe a high increase of the GTP index in years of stagnation, which indicates that, even if the growth of the network decelerated, any additional link significantly increased the connectedness of the network.

One interesting finding from the improved timeline, and a key contribution from this thesis, is that the expansion phases do not immediately follow a stagnation one. In between, there is what we call in figure 8.1 a "planning" phase (written in red). In Cameroon, financial resources have usually been available during years of economic growth, but not only. As we have seen, the different regimes, colonial or sovereign, at different moments in history, have benefited from external funding in the form of non-reimbursable grants or concessional loans. Whatever the reason for which it has been possible to mobilise financial resources, there is a gap of about 10-20 years between the time when the decision to use them for the development of transport networks has been taken and their completion in terms of infrastructure available to users. During that time, the growth of the infrastructure is comparable to a phase of stagnation, but unlike it, the planning phase is characterised by an intense activity related to all aspects of the infrastructure project: formulation of master plans, financial commitments, technical studies, tendering, contracts, and execution of works, etc. This is the reason why period C3 is not considered as a period of network expansion. In the timeline, we have indicated that period C3, from 1945 to 1960, was a "planning" phase. In fact, as we know, it corresponds to the FIDES era. We have seen that the FIDES programme could only begin to reap its fruits when Cameroon's independence was inevitable and that the investments were broadened by foreign aid in the 1960's. We observe that the rates expressing the annual growth of the total length of the transport network and the paved roads are low in C3 (0.35% and 1.1% respectively), even though there was a strong construction activity. However, infrastructure projects took years to be completed and it is only in period N1, the 1960s-1970s, that most of these investments were completed and it could be counted as additions to the network. Indeed, we see that, in this expansion phase in N1, the average annual growth of the network was 4.25% and for paved roads 10.3%. In addition, the index GTP increased significantly during this period (8.52%). As a result, in the late 1970s, all the department capitals were connected. In the 1980s and 1990s, this growth slowed down significantly, although the paved network continued to develop, essentially thanks to the external aid in the form of grants.

The 2000s were years where public works took off again because of debt relief and good economic prospects. However, the results could hardly be seen before 2015, as most of the works were not yet completed. This is the reason why the rates of network length remained low (0.38% for the total network and 2.3% for paved roads). Yet, we assume, based on the various announcements made by the government, that from 2015 onwards, Cameroon entered a phase of expansion (see section 7.5). Future research using updated data and maps will be able to elucidate this supposition. We can also assume that future growth will be mostly relative to the paved road network and that the total network and GTP index will grow less because most of the departmental capitals are already connected (unless there is a massive development of the rail network or alternative highways to the primary network, which seems unlikely).

In sum, we see that, throughout the different cycles of infrastructure expansion-stagnation, in periods of economic dynamism, there is a gap between the political decisions and their actual implementation and, as a result, the growth of the transport network is deferred. Furthermore, the gap produced by this "planning" phase leads us to reflect on an aspect that has not been addressed in depth in this research and is a major concern of governments in developing countries and the international community: how to speed up the preparation and implementation of infrastructure projects so that planning periods can be shortened. While there are many initiatives and studies dedicated to improving and accelerating quality infrastructure delivery, there is little research linking the lessons learned from the past and the actual capacities of governments.

8.3. Overall hypothesis validation and generalisation

Throughout this doctoral research, we have progressively validated the four specific hypotheses that we had put forward for the case study of Cameroon. This allows us to corroborate the overall thesis that we had set out, namely that the articulation between decision-making processes for network formation and the divergence between planned and implemented land transport networks in Sub-Saharan Africa can be characterised by cycles of growth and territorial scale increases, by the dialectic between networked economic development and development by networked territorial control, and by the hierarchical organisation of networks in response to lack of resources. We have been able to do this thanks to an extensive review of the existing literature and the combination of qualitative and quantitative methods in the analysis of past and current decision-making processes for a specific case, Cameroon. The aim of this second to last section is to analyse in more detail the conclusions linked to the validation of the overall hypothesis as well as to provide elements for its generalisation to any country in Sub-Saharan Africa.

Returning to the points we made in the introduction regarding the validity of case study research for the objective set out in this thesis, it is possible to articulate the different steps followed to propose a methodology applicable to any other country. This could be summarised as follows:

1. We develop the theses of Taaffe, Morrill and Gould (1963), based on the cases of Ghana and Nigeria, and of Debrie (2010), for the landlocked countries of West

Africa, and **replicate them for the case of Cameroon over a period of about 130 years**. We make a combined reading between the 6 stages of Taaffe, Morrill and Gould's model and Debrie's three spatiotemporal scales to identify three colonial periods (C1, C3, C3), two national periods (N1, N2) and a regional period (R1).

2. We propose a **network analysis methodology** and a **geohistorical approach** to assess the dynamics of the construction of a country's transport infrastructure:

   2a. We highlight the importance of the analysis of penetration corridors in the colonial periods.

   2b. In the national period, it is fundamental to understand the evolution of the alpha, gamma and GTP connectivity indices, as well as the evolution of the centrality, closeness and betweenness indicators.

   2c. At the regional stage, we look at the impact of the prioritisation of interconnections with neighbouring countries on the functionality of the network.

3. Based on the **fractal-scale properties of transport networks**, we establish that networks in a country like Cameroon have **two mechanisms of evolution**:

   3a. By spatiotemporal growth-stagnation phases, according to which networks increase in scale (local, national, regional).

   3b. By the dialectic between growth according to nodes and privileged routes (population) and networks for the consolidation of the territorial system (surface area).

   A key conclusion of this analysis is that, given the lack of resources, not only economic, but also human and organisational, there is a hierarchisation of the network that is manifested by the paving of certain corridors. The prioritisation of certain axes has an impact on economic development, as certain nodes and dense territories are by-passed/marginalised and consequently impoverished.

4. Our methodology is framed by the postulates of Raffestin (1980), taken up by Debrie (2010), in which he claims that **the move from the maximum to the executed network** is explained by the fact that the groups that hold power reach political, economic and social compromises. In our thesis, we go further and propose a **plan-decide-execute sequence** that allows us to identify at what point these compromises are reached and what consequences they have.

By way of generalisation, we will finish this thesis by analysing this plan-decide-execute sequence in more detail. In fact, a major contribution of our analysis is that it breaks down the political, economic, and technical compromises that Raffestin and Debrie refer to and that lead to the implementation of infrastructure. In this respect, as we have said, Raffestin (1980) defines the maximum network as the one that can guarantee all the most direct connections without any constraint. It is the desired or ideal network, the one with the highest theoretical efficiency. For each historical period, the planned infrastructure is determined based on development policies, objective criteria and technical studies and intends to be as close to the maximum as possible (Samuel, 2017). However, as Raffestin explains, it is diverging from the ideal, as it faces resource constraints, political interferences, and technical restrictions. Then, the decided infrastructure is the one for which a national budget line is foreseen, or which has external funding (for example, a loan agreement with an international financing institution). It may not correspond to the planned, with this discrepancy being again mainly due to political choices and budget limitations (Hirschman, 1967; Muñoz, 2022). Finally, the executed network may diverge from the one planned and/or the one decided for financial reasons or other circumstances, like a limited absorption capacity (Adler, 1965; Hirschman, 1967) or unforeseeable adverse physical conditions (Acemoglu, Robinson & Johnson, 2003; Nunn and Puga, 2012).

Therefore, we propose to make a distinction between maximum, the planned, the decided and the implemented transport network. According to this scheme, as illustrated in figure 8.2, the decision-making processes can be sequenced in three steps:

- from the maximum to the planned network,
- from the planned to the decided network, and
- from the decided to the executed network.

Figure 8.2. Decision-making process from the ideal network to the actual network
(Source: Author)

Indeed, under the scheme we propose the technical, political, and economic commitments that allow the transition from the project to the realised network takes place at three different stages of the decision-making process. This sequencing allows for a better understanding of when and how the executed network ends by diverging from the maximum one. As this thesis reveals, a case study triangulating different disciplines is a useful approach to understand this sequence, as it allows different techniques and methodologies to be combined depending on which of the three stages is being analysed. For instance, a combination of the study of the historical political and economic systems with tools of graph theory used by quantitative geography have full relevance in the case of countries where transport networks are in the early stages of development. Differently, economic geography theories and classical cost-benefit analysis are useful to explain why some infrastructure projects are prioritised over others.

By way of illustration, figure 8.3 represents, first, the stage F of the Taaffe, Morrill & Gould model (1963) as corresponding to the maximum network and, then, three historical maps of the network in Central Africa, each of which corresponds to the planned network, the decided network and the implemented network respectively. The map describing the planned network is from 1923 and is included in the Sarraut Plan for the development of the French colonies. We have chosen this map because the Sarraut plan was in fact conceived by the French Ministry of the Colonies as a strategy to exploit the colonies economically. As such, it emphasised the need to develop the transport infrastructures that could best contribute to that end. For the decided network, we have chosen a map elaborated in 1948, at the beginning of the FIDES era[113]. An interesting aspect of this map is that it was drawn up 25 years after the Sarraut Plan and it differentiates between recognised and unrecognised roads. This is a good indicator of which roads the administrative services decided to build and maintain for motorised vehicles. Today, the alignment of most of the roads follows the one decided in colonial times (Herbst, 2000). Finally, for the executed network, we have included a map from 1993, where it can be seen that, 30 years after independence, the number of paved roads in Central Africa was very low and concentrated around the capital cities.

To say that the maximum network referred to by Raffestin is the last stage (F) of the Taaffe, Morrill & Gould model is a reasonable statement to conclude from this thesis. Indeed, this theoretical stage exemplifies an attempt to represent what would be the hypothetical maximum network referred to by Raffestin for a developing country. As matter of fact, the maximum network is a concept that in practice cannot be represented in a map. Any attempt to represent the maximum network would require assumptions and compromises that would immediately lead us to talk about the planned network. For each temporal and territorial scale, the planned, decided and implemented network corresponds to specific unachieved stages of the Taaffe, Morrill & Gould model (A to E).

As we have seen, this thesis reveals that the infrastructure gap is defined over time in reference to a planned network that does not necessarily correspond to the potential maximum one. Based on our findings, table 8.1 lists the main causes that determine the discrepancies between the maximum network and the implemented network, and which can be generally applied to other Sub-Saharan African countries that were colonised.

[113] https://gallica.bnf.fr/ark:/12148/btv1b53192486g

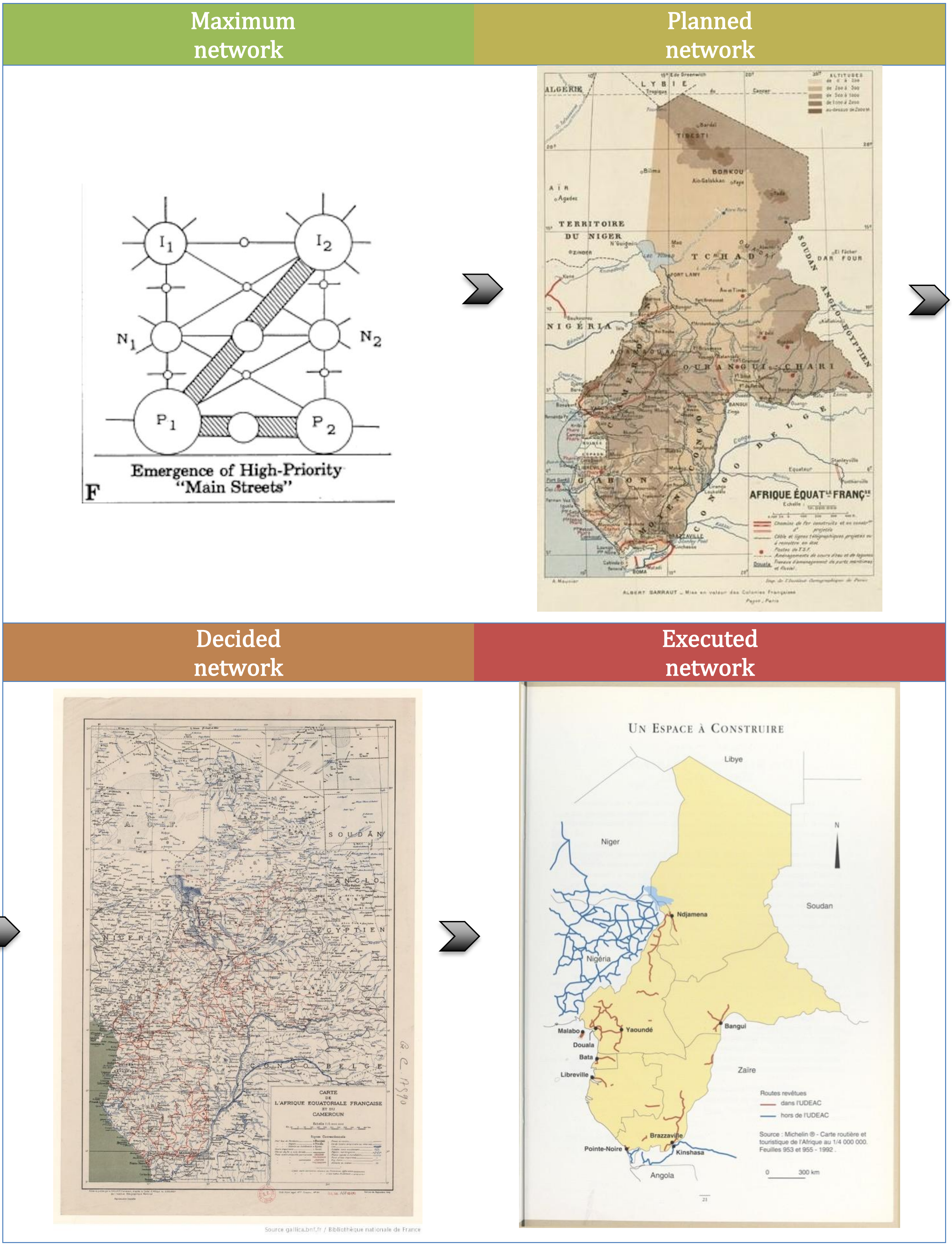


Figure 8.3. From the maximum to the executed network: an illustration for the case of Central Africa (Source: Author)

Maximum network	Planned network	Decided network	Executed network
Historical period	Main reasons for discrepancy in this period		
Colonial period *(1885 – 1960)*	- access areas with high economic value - control of the colonial territory - disregard of pre-existing economy	- self-sufficiency of the colonies - rely on private investments	- natural geography - availability of labour
Maximum network	Planned network	Decided network	Executed network
Historical period	Main reasons for discrepancy in this period		
National period *(1960 – 1982)*	- rentier states, urban bias - territorial control, capital city - pan African ideals, Eurafrica	- neo-patrimonialism	- absorption capacity - corruption - lack of maintenance
(1983 - 1999)	- donors' agendas	- structural adjustment programmes	
Maximum network	Planned network	Decided network	Executed network
Historical period	Main reasons for discrepancy in this period		
Regional period *(2000 – 2015)*	- globalisation, trade paradigm - African Union - China extractive logic	- connecting African capitals and main ports - debt sustainability - environmental, social and governance safeguards - public-private partnerships	- absorption capacity - corruption - lack of maintenance - security - lack of harmonised standards

Table 8.1. Main causes determining the divergence between the maximum network and the implemented network (Source: Author)

For the *colonial period*, the case of Cameroon and the work of several authors for other countries show that, with the arrival of the European powers to Africa, the potential convergence between the planned and the maximum network was significantly disrupted. Not only were pre-existing connections disregarded, but colonial infrastructures were planned to give access to the areas of greatest economic value to the metropolis and to control the territory militarily and administratively. In addition, given the economic self-sufficiency doctrine and reliance on the private sector, the difference between what was planned and what was decided to finance was remarkable. Finally, the infrastructures that had been decided upon faced many problems in their implementation, mainly due to the difficult terrain, weather conditions and the lack of manpower willing to work on such projects.

In the *national period*, the new powers maintained the same economic rationale based on the export of raw materials and agricultural products. Independent countries thus became rentier states (Clapham, 1966), sustaining their economies by exporting raw materials and exploiting their rural areas for the benefit of the urban elites (Lipton, 1977). The literature review and the example of Cameroon show that this situation marginalised many areas of the countries, which only had the opportunity to connect to the capital with roads that expanded following a logic of control of the national territory. At the same time, there was a certain neo-colonial inertia and pan-Africanist aspirations that allowed some regional connections to develop, essentially between countries that belonged to the same bloc during colonisation.

The divergence between the planned and the executed network was aggravated by nepotism whereby many of the transport infrastructures were prioritised based on communitarian criteria depending on the dominant groups in power. Also, from 1985, with the severe downgrading of macroeconomic indicators and the debt crisis, the entry of structural adjustment programmes was a major constraint on governments' ability to finance the planned infrastructure. In this sense, network planning and decision-making was at the mercy of the donors' agenda, which could lead to additional deviations from the maximum network.

In all cases, a determining factor that distanced the infrastructures that were built from the maximum, planned and executed network was the limited absorption capacity of African administrations (Adler, 1965; Hirschman, 1967). It was not only a problem of financing, but also of the existence of sufficient and qualified human resources, of good contractors, of the capacity to maintain the infrastructures, etc. Moreover, widespread corruption reduced the governments' capacity to implement and manage the network.

The planned network during the *regional period* can be well understood using the economic geography references reviewed. In recent years, theories linking transport, trade and growth have prevailed in the policy-making arena. They advocate a concentration of investments in favour of industrial clustering, and the necessary geographically unbalanced growth to be followed by spill-over effects (World Bank, 2009b). Remarkably, the economic transport corridors favoured in the latter period corroborate classic models of transport geography, such as the Taaffe, Morrill & Gould (1963), as they correspond to the "High-Priority Main Streets". At the same time, there is a resurgence of extractive routes from the mines to the ports. We see that this trend, which was the paradigm during the colonial era, is being re-imposed in large part due to the entry of foreign actors such as China.

In the regional period, the move from the planned to the executed network is affected by plans to interconnect all the African capitals because of the continental policies of the African Union. This deviation is also explained by the continuing strong influence of multilateral development banks that favour multi-country projects. These routes, which attempt to interlink the continent, are not always economically justifiable. At the same time, another factor is that financial institutions are tightening their social and environmental requirements and are being more cautious to avoid generating unsustainable debt. This stricter criterion has led many countries to turn to non-traditional donors such as China, Turkey or Brazil, or to seek solutions in the form of public-private partnerships. In these cases, the infrastructures that are finally decided may be very different from the ones planned as they are often the result of unsolicited bids.

Finally, this research reveals that, over the last decades, the implementation capacity of most African countries has not been substantially improved and corruption levels remain high. Consequently, the levels of infrastructure finally executed are low. In addition, multi-country infrastructures are more difficult to build due to the absence of common regional standards. Not to mention situations, such as in Cameroon, where projects take a long time to start and when they are finally under construction, they coincide with a deterioration of the security situation that prevents them from being built according to the initial planning.

8.4. Final considerations, improvements, and further research

This thesis proposes a methodology for the study of transport infrastructure as a combination between geohistorical phases and dynamics of network evolution. Based on the models and postulates of Taaffe, Morrill and Gould, Raffestin and Debrie, our methodological approach consists of the characterisation of the evolutionary phases, according to growth-stagnation cycles, the analysis of the dialectic between accessibility for the population and territorial coverage, and the assessment of investment and maintenance costs in relation to the real capacity to implement the network. It would be appropriate to apply these research methods to understand the development of the transport network in other African countries and at different scales. Other case studies, using the methodology developed in this thesis will undoubtedly enrich our knowledge of transport corridors in Africa by broadening our understanding of the new economic and political forces that shape transport infrastructure in the continent. In turn, it will contribute to improving decision-making processes, which is ultimately the objective of this research.

Furthermore, it would be relevant to use these methods to understand better the new extractive logic of the capitalist world-system, given the consolidation of a multipolar world that needs raw materials to sustain itself and to allow for an ecological transition that avoids a global climate and biodiversity catastrophe. Indeed, although this thesis has focused on the 130 years from 1884 to 2015, during its completion, global geopolitics have changed considerably. This is the reason why we have included our work on the EU prioritisation of corridors in Africa as relevant publications contributing to this thesis. In Baranzelli *et al.* (2022a), we made a ranking of 55 African transport corridors using multi-criteria analysis and different development scenarios, including aspects not linked to export and import, such as accessibility for the population and the protection of biodiversity. The report confirms the assumptions we made in the chapter of the book on Transport Corridors in Africa (Oliete Josa & Magrinyà, 2022), whereby we claimed that the density of population should be weighted as main criteria for corridor prioritisation.

While the Baranzelli *et al.* (2022a) study led to the selection by Europe of 11 strategic corridors in which to focus the investments within the framework of the EU-Africa Global Gateway Investment Package[114], in Baranzelli *et al.* (2002b), we further analysed the strategic corridors selected, this time looking at mineral extraction in Africa. We conclude that although the multi-criteria analysis was intended to avoid an exclusively raw material extractive approach, 5 of the 11 corridors can be considered as sources of mineral resources. Overall, these two works demonstrate the validity of our assertion according to which we are in a regional period (R1). As infrastructure planning and implementation in Africa is currently addressed on a regional corridor scale, the methodology proposed in this research can be exploited to get a better understanding of the contemporary process of transport network growth in Africa, notably regarding the export of critical raw materials.

Regarding future research about Cameroon, as we have explained in this thesis, in 2015, the country had acceptable levels of connectedness and its network corresponded to a “grid” configuration. Improving connectivity to achieve a "delta" configuration would require the construction of alternative routes to the current ones, such as new motorways or railways, which seems unlikely. However, as we have seen, the main problem lies in the quality of the existing roads, the vast majority of which are not asphalted. Given that a significant number of roads were at the end of this research being upgraded, it would be relevant to re-characterise the network that will exist in 2025 or 2030. To determine how it has evolved, we suggest using the different calculations used in this study:

[114] https://ec.europa.eu/commission/presscorner/detail/en/fs_22_1119

First approach: evolution of network construction

- identification of geohistorical periods.
- shortest-path network analysis.
- connectivity indices of the graph and centrality indicators.
- infrastructure provision including the use of the fractal index.

Second approach: urban system and network maintenance

- evolution of the territorial distribution of city systems.
- evolution of the territorial distribution of poverty rates.
- investment levels in metropolitan areas vis-à-vis inter-urban links.
- vehicle operating costs linked to road deterioration.

To this, we propose to add the calculation of the connectivity indices (alpha, gamma and GTP) by disaggregating the network between asphalt and gravel roads. This will give a more accurate picture of the connectivity of the network and how, by adding a link, its performance improves. For instance, the Batchenga-Ntui-Yoko-Tibati-Ngaoundéré road, the central corridor, is currently being paved. In our calculations, it already existed since 1930, so connectedness as such will not improve. However, the fact that it will be an asphalt road will have a major impact on the distribution of trips in the network.

In future research, it would be relevant to confirm whether Cameroon is in a phase of network expansion and what is the real weight of these investments in relation to the public budget. In addition, it would be important to understand whether the tendency towards a homogenising planning of the asphalted network throughout the territory is maintained instead of prioritising its development where more people live. In the future, it may even be possible to determine whether Cameroon enters a period R2 of network development, with different features from those observed in period R1, which we have studied quantitatively until in 2015.

9. Bibliography

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10. Annex – Publications

Chapters in books

1. Oliete Josa S. & Magrinyà F. (2022). From Priority Projects to Corridor Approaches: The African and European Continental Transport Networks put into Perspective, in Nugent P. Lamarque H. (eds.), *Transport Corridors in Africa*, Edited Volume, Boydell and Brewer, Suffolk
   https://boydellandbrewer.com/9781847012944/transport-corridors-in-africa/

Indexed journals

2. Oliete Josa, S., & Magrinyà, F. (2018). Patchwork in an interconnected world: the challenges of transport networks in Sub-Saharan Africa. *Transport Reviews*, 38(6), 710-736. Print ISSN: 0144-1647 Online ISSN: 1464-5327.
   https://doi.org/10.1080/01441647.2017.1414899

3. Torres Martínez A.J., Oliete Josa S., Magrinyà F. & Gauthier J.M. (2018). Cost-effectiveness of enforcing axle-load regulations: The Douala-N'Djamena corridor in Sub-Saharan Africa, *Transportation Research Part A: Policy and Practice*, Volume 107, 216-228, ISSN 0965-8564.
   https://doi.org/10.1016/j.tra.2017.11.016

4. Baranzelli, C., Blengini, G. A., Oliete Josa, S., & Lavalle, C. (2022b). EU–Africa Strategic Corridors and critical raw materials: two-way approach to regional development and security of supply. *International Journal of Mining, Reclamation and Environment*, *36*(9), 607-623.
   https://www.tandfonline.com/doi/full/10.1080/17480930.2022.2124786

Research reports (not included in this doctoral dissertation due to its size)

5. Baranzelli, C., Kucas, A., Kavalov, B., Maistrali, A., Kompil, M., Oliete Josa, S., Parolin, M. & Lavalle, C. (2022a). *Identification, characterisation and ranking of strategic corridors in Africa*, EUR 31069 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-76-52430-4, doi:10.2760/498757, JRC128942.
   https://publications.jrc.ec.europa.eu/repository/handle/JRC128942

Chapter 4

From Priority Projects to Corridor Approaches: African and European Transport Networks in Perspective

Sergio Oliete Josa and Francesc Magrinyà

Introduction: Are African and European Transport Networks Comparable?

In many ways, European integration has inspired African states to move towards a more ambitious African Union, and there are clear parallels between the institutional arrangements of the AU and the EU. However, a number of authors have warned of the limitations involved in making any comparisons, starting from the fact that African states have ceded very restricted sovereignty at a supranational level compared with Europe. In this chapter, we pose the question of whether the African transport network and the Trans-European Transport Network (TEN-T) are comparable. We want to see whether the criticisms of and lessons learned from the European experience are applicable to the development of the African Regional Transport Infrastructure Network (ARTIN), as supported by the Programme for the Infrastructure Development of Africa (PIDA). By reviewing the literature that highlights the methodological shortcomings in the planning process of the TEN-T, we analyse the similarities and differences between the two continental ambitions from different standpoints: official narratives, stakeholder analysis and planning and funding instruments. We conclude that support for the transport sector is an appropriate way of strengthening African integration, but any ambitions to do so need to be balanced in accordance with the existing resources. In particular, the completion of 'missing links' can have significant structuring effects, but it should not be done at any cost, because planning errors can have very negative consequences. National political interference, low cost-effectiveness and a high environmental impact are common criticisms in the case of the TEN-T. Africa suffers considerably from the same drawbacks, with the additional problems of higher investment

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needs, insufficient funding, a larger surface area to cover, lower densities and lack of maintenance. By looking at the European experience, Africa may be able to improve and accelerate its own process.

Transport is one of the necessary conditions for achieving Africa's aspirations as they have been set for 2063, but it is not adequate in itself.[1] It is one of the sectors that has the most investment needs and the highest cost of maintenance.[2] It is also one of the key sectors of an economy in which the provision of infrastructure is lower than it is on other continents. In Sub-Saharan Africa, the population lives far from economic markets: on average, it is located 13 per cent further away than populations in other parts of the world. This figure increases to almost 50 per cent when compared to Europe.[3] 16 out of the 54 countries are landlocked, and even some of those with direct access to the sea have vast inland areas located far from the coast, as is the case with DRC. The railway network has hardly expanded at all since colonial times, the lines are unevenly located (they are mostly in Southern Africa) and density is low, ranging from 30 to 50 kilometres per million people, or about 2.5 kilometres per thousand square kilometres.[4] In Europe, the density of the rail network is between 200 kilometres and 1,000 kilometres per million people, nearly 50 kilometres per thousand square kilometres. Similarly, road density in Africa – 3.4 kilometres per thousand people – is less than half the global average, and this is reduced to one-fifth when comparing its paved roads with those on other continents.[5] In Europe, according to Eurostat, road density is about 8.1 kilometres per thousand people.

1 In 2063, Africa will commemorate 100 years since the Organisation of African Unity (OAU) was established: Africa Union <https://au.int/en/agenda2063/aspirations>.

2 V. Foster and C. M. Briceño-Garmendia (eds), *Africa's Infrastructure: A Time for Transformation*, The World Bank, 2010, pp. 6–7.

3 P. Manners and A. Behar, *Trade in Sub-Saharan Africa and Opportunities for Low Income Countries*, Background Paper for the World Development Report 2009: Reshaping Economic Geography, Washington, D.C., 2009, p. 5 <http://hdl.handle.net/10986/9242>.

4 African Development Bank, *An Integrated Approach to Infrastructure Provision in Africa*, Tunis, 2013, pp. 13–14 <https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/Economic_Brief_-_An_Integrated_Approach_to_Infrastructure_Provision_in_Africa.pdf>.

5 K. Gwilliam, 'Africa's Transport Infrastructure: Mainstreaming Maintenance and Management', Washington, D.C., 2011, pp. 22–26 <http://hdl.handle.net/10986/2275>.

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In Sub-Saharan Africa, there is a vicious circle of a lack of competitiveness, poor domestic revenue mobilisation, low investment in transport infrastructure and high transport costs. Transport prices are not the result of a lack of good infrastructure alone, however; they are also related to a chain of defects caused by non-physical barriers along the transport corridors, starting at the ports. Ports are essential elements of the inter-modal connectivity of these corridors, as they are giving access to inland areas and landlocked countries. Africa is highly dependent on ports in order to have access to international trade. While it only contributes to 2.7 per cent of global trade by value, its ports represent 7 per cent of global loaded tonnage and 5 per cent of unloaded tonnage.[6] In general, however, they do not fulfil their function satisfactorily. Their performance levels are poor, and their infrastructures and services are not up to international standards. The containerisation of African ports remains low, and globally they only receive and dispatch 4 per cent of containers, mainly to import manufactured goods. Only four of the top 100 global container ports are in Africa. The low level of efficiency is also reflected by crane productivity and dwell times: while crane productivity is 25–40 moves per crane per hour on average, in West Africa it is only 20 moves. Cargo dwell time is also high in Sub-Saharan ports: on average, cargo spends more than two weeks at the ports, while on other continents the average period is less than a week.

An increasingly challenging situation for African ports is their interface with inland transport modes (road and rail). Many urban areas around ports are becoming increasingly congested, and goods cannot be easily warehoused or moved out of cities. Dry ports on the outskirts of densely-populated urban areas would be vital to increase the efficiency of the logistics chains. Overall, poor infrastructure in urban nodes (by-passes, public transport, underground railway systems, etc.) is becoming a major obstacle that must be added to the already flawed land transport.

A number of authors have looked at the challenges faced by African transport networks and emphasised the influence history and geography have on them.[7] These two factors lie at the origin of the major differences between African and

6 UNCTAD (United Nations Conference on Trade and Development), *Review of Maritime Transport*, Geneva, 2017 <https://unctad.org/es/node/29022>.

7 W. Naudé, 'Geography, Transport and Africa's Proximity Gap', *Journal of Transport Geography*, 17:1, 2009, 1–9; J. Debrie, 'From Colonization to National Territories in continental West Africa: the Historical Geography of a Transport Infrastructure Network', *Journal of Transport Geography*, 18:2, 2010, 292–300; S. Oliete Josa and F. Magrinyà, 'Patchwork in an Interconnected World: the Challenges of Transport Networks in Sub-Saharan Africa', *Transport Reviews*, 38:6, 2018, 710–36.

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European transport systems. The Sahara desert, the difficult living conditions in the Equatorial forests and a lack of navigable rivers are some of the geographical determinants that are considered to have had a historical impact on the development of transport networks. Low density and sparse urbanisation have also heavily influenced their development. These problems do not exist in Europe. Furthermore, the way the borders of colonial empires were established created terminuses for many roads and railways. The political legacy and poor economic performance of the newly-independent states have also unquestionably made a contribution towards holding back transport in Africa.

With all these substantial differences, does it make any sense to compare transport networks in Africa and Europe? As we will see in the paragraphs that follow, the discourses in Africa are more about connectedness (*connexité*), where the connections between nodes have not been completed yet (missing links). As Dupuy has defined it,[8] the term *connexité* means the links between subsystems. In Europe, the network is completed in most cases: it is more an issue of connectivity (bottlenecks), understood in the sense of the existence of a multiplicity of links within a connected network.

If one takes the historical context and technological progress into consideration, it would be a mistake to assume that African networks will follow the same path towards attaining full connectedness as Europe's did. However, as many authors have noted,[9] there are common specificities and logics of transport networks that correlate with territorial organisation. In this chapter, we argue that despite there being major differences, there are also similarities between African and European transport networks, in particular with regard to recent planning and decision-making processes. Good practices, as well as the errors made, in the European context may help improve policy-making and project implementation in Africa. We will first analyse the differences between transport policies on the two continents and then assess the current infrastructure development programmes in Europe and Africa.

8 G. Dupuy, 'Propriétés des Réseaux', *Systèmes, Réseaux et Territoires. Principes de Réseautique Territoriale*, Paris, 1985, pp. 65–100.

9 E. J. Taaffe, R. L. Morrill and P. R. Gould, 'Transport Expansion in Underdeveloped Countries: A Comparative Analysis', *Transport and Development*, London, 1973, pp. 32–49; Dupuy, 'Propriétés des Réseaux'; B. Hoyle and J. Smith, 'Transport and Development: Conceptual Frameworks', in B. Hoyle and R. Knowles (eds), *Modern Transport Geography* (2nd edn), Chichester, 1998, pp. 13–40.

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Transport Policies in Africa and Europe: An Apparently Far-fetched but Useful Comparison

Before analysing the African and European programmes for developing their respective transport corridors, it is important to examine more thoroughly the process of regional integration in both continents and its consequences for transport policies. Fioramonti and Mattheis[10] have suggested a framework for comparing the construction of the two continental unions that shows that despite certain symbolic institutional similarities where the AU has been inspired by the EU, the integration logics applied on the two continents differ. For instance, in contrast with the African experience, Europe's has been characterised by a gradual process of integration starting out from six countries, restrictive membership requirements and the transfer of significant sovereignty roles to a supranational level. However, the main distinction between the two processes that influences how the transport sector is addressed resides in 'the drivers of regionalism'. While European integration has been driven by trade integration, market liberalisation and to some extent social cohesion, integration in Africa has focused on peace and security issues. The low volumes of intra-African trade (estimated to be 12.8 per cent of total African international trade) are fundamental when it comes to explaining the low level of competitiveness of many countries.[11] Except for certain limited experiences at a regional level, it was only in 2019 that the African Continental Free Trade Area (AfCFTA) came into effect, and it is still difficult to precisely anticipate the pace of implementation, the increases in trade flows and the advantages of the AfCFTA for African economies. Conversely, the project to connect Europe with transport corridors is a 'by-product of the European single market project'.[12]

In view of this major difference in terms of drivers of continental integration, it is important to study how it affects transport continental policies in Europe and Africa and if it has practical consequences for the implementation of their respective infrastructure programmes. Three different aspects are considered and compared in the following sections: the key players, the official narratives and the planning tools.

10 L. Fioramonti and F. Mattheis, 'Is Africa Really Following Europe? An Integrated Framework for Comparative Regionalism', *JCMS: Journal of Common Market Studies*, 54(3), 2016, pp. 674–90.

11 M. Bosker and H. Garretsen, 'Economic Geography and Economic Development in Sub-Saharan Africa', *The World Bank Economic Review*, 26(3), 2012, pp. 443–485 <doi: 10.1093/wber/lhs001>.

12 A. Aparicio, 'The Changing Decision-Making Narratives in 25 Years of TEN-T Policies', *Transportation Research Procedia*, 25, 2017, pp. 3715–24.

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An Analysis of the Key Players

Overall, institutional arrangements seem to be similar on both continents: planning is at a central level, while implementation is at a national level. In Africa, PIDA officially covers development of the transport network. In Europe, the programme guiding transport infrastructure is the TEN-T. In theory, where priority projects are to be adopted, the decision-making process is in both cases the result of a bottom-up consulting process in which proposals put forward by member states are validated at a high political level after being reviewed by experts. In Africa, the AU Assembly of Heads of State and Government takes these decisions, while in Europe they are adopted by the EU Transport Ministers at the Council of the European Union. African regional economic communities (RECs) often play a more important role in the choice of priority projects than do countries, as is often the case in other areas (for example, monetary and security). RECs usually have their own regional infrastructure master plans, which have been the basis for the elaboration of the PIDA at a continental level.

In practice, the African and European institutional architectures are quite different. Europe's relatively longer experience has helped it reduce complexity and provide more flexible arrangements. These days, the TEN-T is seen more as a policy than an infrastructure programme. The development of the Trans-European corridors is guided by work plans that outline the objectives for action up to 2030. They include investments, preparatory activities, studies and policy-oriented actions. They are updated regularly on the basis of stakeholder consultations[13] and new technical studies. For each of the nine corridors and two horizontal priorities, the European Commission appoints 'European Coordinators', high-level figures in charge of overseeing, facilitating and reporting on the work plans. One important aspect of their mandate is consultation with corridor forums, which are consultative bodies made up of member states and significant stakeholders. In addition, for more than a decade, TEN-T Days have brought together ministers, members of the European Parliament, the European Coordinators and representatives of the European Investment Bank, the European Commission and TEN-T stakeholders to discuss progress on the implementation of the trans-European transport network.

In support of these work plans, the European Commission has put in place a number of funding instruments that combine grants, loans, guarantees and other innovative financial instruments. In particular, the Connecting Europe Facility

13 Generally, stakeholders include member states, infrastructure managers/authorities, regional and territorial representatives, municipalities, metropolitan authorities and transport operators.

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(CEF), which is managed by the Climate, Infrastructure and Environment Executive Agency (CINEA), co-finances actions submitted by the various stakeholders and selected through competitive calls for proposals. Nevertheless, although several other funding sources exist, such as the European Structural and Investment Funds and the European Fund for Strategic Investment, the largest portion of funding comes from the member states' national budgets.

In Africa, the current Institutional Architecture for Infrastructure Development in Africa (IAIDA) governing PIDA is the result of a series of attempts to accommodate numerous initiatives that have emerged with the aim of effecting a rapid reduction of the infrastructure deficit. Many of the initiatives in recent decades have been proposed by charismatic African presidents like Mbeki and Zuma in South Africa, Wade in Senegal and Kagame in Rwanda. Once a political action of this kind has been launched, it has been extremely difficult to reach a compromise to avoid adding institutional complexity. When these new structures are created at a national level, new management units are generated that absorb agents and officials. These programmes are difficult to dismantle once they have attained their objective or, as is usually the case, they are not considered to be efficient enough and are superseded by new, and supposedly improved, initiatives. A good example of this phenomenon is the frequent reforms that the New Partnership for Africa's Development (NEPAD) has undergone since its creation in 2001. It is still hard for an outsider to understand the division of labour between the NEPAD mandate and the AU Commission. The most recent redesign and attempt at rationalisation was the transformation in 2018 of NEPAD's structures into the African Union Development Agency, which is known by the acronym AUDA-NEPAD. This agency, together with the African Union Commission (AUC), the African Development Bank (AfDB), the United Nations Economic Commission for Africa (UNECA) and the RECs, is now seen as the lead organisation supporting the member states in their implementation of the PIDA.

At a planning level, the AU has also made efforts to rationalise the myriad consultative entities intended to assist the decision-making process. The most recent unifying strategy was the Agenda 2063, which was launched in 2013, and sets out the AU's long-term development vision. The PIDA is the continental framework for Africa 2063's infrastructure development as decided at the Malabo Conference of Ministers for Transport in 2014.

Like TEN-T Days, the PIDA Week has been organised annually since 2015 to co-ordinate and create synergies among the different stakeholders. Although it is not a statutory AU event, it brings the PIDA's leading implementing organisations together with representatives from, for example, the PIDA Steering Committee, the Council for Infrastructure Development, the Infrastructure

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Consortium for Africa, the Continental Business Network. Member states also usually attend PIDA Weeks, often in the form of representatives from ministries, the private sector, civil society, bilateral and multilateral development finance institutions, among others.

From Official Narratives to Special Interests

Modern inter-state initiatives for the development of continental transport infrastructure are actually older in Africa than in Europe. The UN Economic Commission for Europe (UNECE) began to define the E-Road network in Europe in the 1950s, but it was not until the 1990s that Europe established a common planning and funding scheme. In Africa in the early 1970s, UNECA defined a network of roads linking all the capitals of the continent to be known as the Trans-African Highway (TAH), which consisted of nine main roads with a total length of 59,100 kilometres (see Map 4.1). The alignment of some of them, like the Trans-Saharan Highway, had already been designed by the colonial powers. Starting with the Lagos–Mombasa highway, implementation of the TAH network was monitored by intergovernmental co-ordinating committees, with UNECA leading the process as the executing agency. Since then, the TAH network concept has been the prevalent accepted point of reference for African states, RECs and donors. For instance, since the establishment of the TAH, the project appraisal documents produced by many development agencies have justified the choice of a specific road by the fact that it constitutes a section of a trans-African highway. In 2012, the TAH network was used as the basis for the definition of the Africa Regional Transport Infrastructure Network (ARTIN), which is the reference point for the PIDA. The ARTIN consists of the TAH network, which now has 10 axes, plus 40 key corridors.

As mentioned above, European integration was driven by the goal of the single market, and the notion of a trans-continental transport infrastructure was closely connected to it. Likewise, in the case of Africa, the motivation behind the initial TAH network was economic integration and increasing African trade, with one noteworthy difference from Europe: 'opening up new areas with promising agricultural and mineral potential'.[14] In both cases, however, besides the trade angle, other interests and arguments have emerged to drive development of the transport agenda. In the first place, there is the pursuit of political legitimation

14 Economic Commission for Africa, *Resolution Adopted by the Conference of Ministers, 226(l): Trans-African Highway*, Tenth Session, Conference of Ministers, Tunis, 8–13 February 1971.

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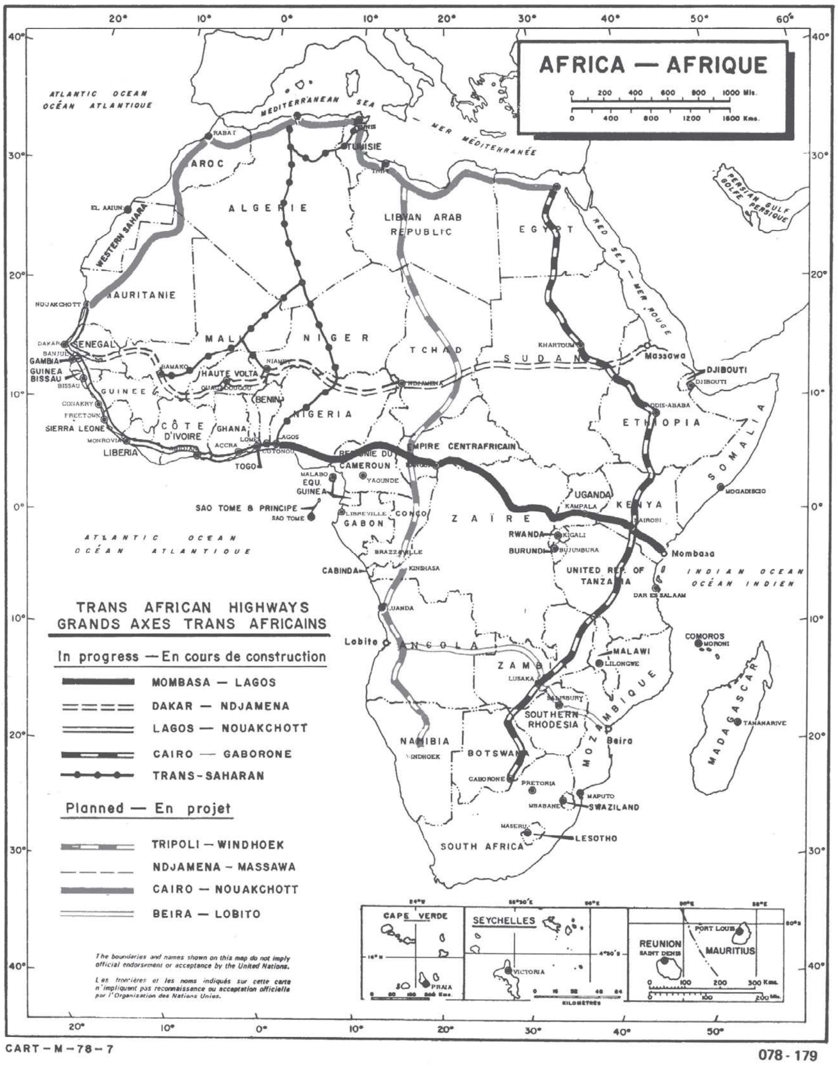

Map 4.1. Trans-African highways as defined in 1978.
(Source: Ousmane Gueye, Bangui Conference on Transport and Communications, UN Economic Commission for Africa, 1978.)

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by regional organisations. In Africa, in the early decades following independence, there was a strong rivalry between the Organisation of African Unity (OAU), the UN Development Programme (UNDP) and UNECA.[15] For the latter, the TAH network, and later the UN Transport and Communications Decade in Africa (1978–1988), were initiatives that made it possible for the organisation to bring advisory and co-ordination functions together on issues of major importance for the African states. Later on, as we explained in the previous section, this role was gradually transferred from UNECA to NEPAD and the AUC.

In Europe, like agriculture and the free movement of people, services and capital, the common transport policy was introduced by the Treaty of Rome, which created the European Economic Community in 1957. However, it was not until the Maastricht Treaty was signed in 1993 that the Trans-European Networks were adopted as an integral part of Community policy. This was because for the member states, the TEN-T policy *de facto* represented a transfer of critical decisions on important aspects of their territorial sovereignty,[16] and they only agreed to move forward when the European Court of Justice intervened.[17] As a result, by adding long-term planning responsibilities to the TEN-T, the European Commission gained significant power and visibility *vis-à-vis* European citizens.

Another narrative besides economic integration is the contribution made by transport networks towards strengthening a shared continental identity. In Europe, this coalesces around the cohesion policy, of which the TEN-T is a central tool for reducing regional disparities. Behind the official rhetoric of 'harmonious development'[18] promoting balanced and sustainable growth, Europe has faced the need to rally citizens from poorer countries that are suffering from the consequences of liberal policies inherent in the single market.[19] In this sense, cohesion has been presented as an expression of solidarity, as a policy to make Europe's values a reality. In practical terms, it results in the choice

15 S. Misteli, 'Gardiner, Robert Kweku', *IO BIO, Biographical Dictionary of Secretaries-General of International Organisations*, Bob Reinalda, Kent J. Kille and Jaci Eisenberg (eds) <www.ru.nl/fm/iobio> [Accessed 15 August 2019].

16 F. Piodi, 'The Financing of Trans-European Transport Networks', *Directorate General for Research, Working Document Transport Series E-4*, Brussels 1997, pp. 24–25.

17 A. Faludi, 'Territorial Cohesion Policy and the European Model of Society', *European Planning Studies*, 15:4, 2007, pp. 567–583 <DOI: 10.1080/09654310701232079>.

18 Article 174 of the Treaty on the Functioning of the European Union.

19 D. Peters, 'Cohesion, Polycentricity, Missing Links and Bottlenecks: Conflicting Spatial Storylines for Pan-European Transport Investments', *European Planning Studies*, 11:3, 2003, pp. 317–39.

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of priority projects based on political commitments and not on cost-effective considerations. In Africa, where insufficient internal trade and low levels of inter-state traffic make it hard to justify the economic feasibility of some of the trans-African highways, recourse to pan-African ideals can easily be discovered behind the official storylines. From an economic point of view, linking all the African capitals by road makes little sense in some cases, in particular where long distances have to be travelled across the Sahara Desert or tropical forests. At the same time, it is a reasonable political aspiration for Africa to think that all its capitals can be joined by road from the neighbouring country. In fact, some prominent African decision-makers, like Adebayo Adedeji, who was UNECA's Executive Secretary during the UN Decade for Transport and Communications, have openly expressed their scepticism about focusing on trade to boost African integration and have advocated backing it with infrastructure development.[20] As is the case with the European cohesion policy, the goal of opening up landlocked countries and isolated regions is customarily included in official African documents on transport. As a 2011 preparatory study for the PIDA noted, continent-wide ambitions have proved to be hard to achieve: 'Lack of alignment with national and regional priorities is a primary failure factor, as good ideas become orphan projects. For example, segments of the Trans-African Highways that correspond to the priorities of the country involved have been built, but segments that do not fit country priorities have stagnated.'[21]

This brings us back to the economic justification for trans-continental corridors. In the case of Europe, Peters[22] mentions other storylines, such as polycentricity and bottlenecks. Polycentricity is a narrative that proposes competition and complementarity between cities and regions in the context of the common market. This is a controversial line of reasoning because it might be argued that it goes against cohesion policy. While the 'EU's cohesion policy aims to strengthen economic and social cohesion by reducing disparities in the level of development between regions',[23] the principle of polycentricity is that cities should be interconnected by high-speed transport, while many rural areas and peripheral regions may be bypassed. In the case of Africa, even though the concept of growth poles is often utilised at the national level, the logic of polycentricity is not on the agenda at a continental level, probably because of

20 S. K. B. Asante, *African Development: Adebayo Adedeji's Alternative Strategies*, London, 1991, pp. 8–13 and pp. 105–06.

21 SOFRECO, Study on Programme for Infrastructure Development in Africa (PIDA), Phase I Study Summary. Clichy, 2011.

22 Peters, 'Cohesion, Polycentricity, Missing Links and Bottlenecks', pp. 317–39.

23 https://ec.europa.eu/regional_policy/en/policy/what/glossary/c/cohesion-policy.

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the small size of the market. The bottleneck storyline is evoked in the African context, but almost exclusively to describe congestion in ports due to a lack of appropriate infrastructure, and more especially to their management failings. In Europe, by contrast, the concept is far more widespread. It is associated with the insufficient capacity of already existing connections, in particular between or through urban nodes. Again according to Peters, the bottleneck is a concept that is not exempt from controversy. Policy-makers have not defined it accurately, and it raises environmental concerns as to the limits to which infrastructure capacity can be expanded. In addition, it is a notion that is associated with places where infrastructure already exists, and these are normally the wealthier ones.

A very common current argument is built around the notion of 'missing links'. It was introduced in official documents in both unions dating back to the 1980s, albeit with different implications. In Africa, as we mentioned earlier, it refers mainly to matters of *connexité*: that is, sections of the trans-African highways that really do not exist, or are surfaced with earth and gravel and need to be upgraded to paved standards. In 2017, according to the AUC's estimates, TAH missing links covered 4,300 kilometres out of a total of 61,870 kilometres. In Europe, most links already exist in one mode or another, and the objective is to reduce time or increase capacity, in particular on cross-border sections: it is simply a matter of improving connectivity. In both cases, however, behind the rhetoric of 'missing links' lies the need to justify significant investments, the economic returns from which are not evident. The choice of these priority projects is often political, as we have seen in the previous paragraphs but, as Peters[24] points out for the case of Europe, the construction industry also lobbies extensively in favour of them. In Africa, while the interests of construction firms carry less weight, the 'missing links' attract great interest from the ruling class, not only due to political benefits but also because of the personal gains they can obtain in a corrupt procurement system. For their part, donors and development banks play a central role in promoting the completion of inter-state infrastructure. Firstly, the increase in intra-African trade is a top priority in aid agendas today, even though, in many cases, the transport demand that will be generated will be low in the short and medium term. Secondly, massive public spending on infrastructure is still viewed as a stimulus for the economy. Last, but not least, 'missing links' can help maintain lending operations at satisfactory levels because they are usually funded with regional allocations, which are easier to mobilise (they come at the top of countries' strategies and are not in competition with other national priorities).

24 Peters, 'Cohesion, Polycentricity, Missing Links and Bottlenecks', pp. 317–39.

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Planning Methods and Financing Tools

As we have seen in both Europe and Africa, planning of trans-continental corridors is to some extent transferred to a union level, while the implementation of projects remains the responsibility of member states. Although the decision-making concept may be used in official documents, notably by the AU, the word 'planning' seems to be more appropriate in both cases because the inclusion of a project in the PIDA or the TEN-T does not mean that it has actually been 'decided'. In practical terms, there is a major difference between the two processes: the AU does not provide funds for investment in infrastructure from its own budget; at most, it mobilises grants from international donors and channels them to certain projects or uses them for institutional support.[25] The absence of AU funding instruments to support the PIDA is an institutional weakness that limits its capacity to influence how member states prioritise trans-continental projects. In Europe, the situation is rather different, and the existence of various sources of funding facilitates the elaboration of work plans as an inclusive decision-making process with a high likelihood of being implemented. However, some authors[26] have criticised the European planning process for not taking efficiency and environmental aspects into adequate consideration and exaggerating the added value of some projects. Instead of promoting sustainable, balanced and genuinely pan-European projects, the TEN-T decision-making process is, according to these studies, not transparent enough, and is heavily biased by corporate demands and national politics.

In any case, one common occurrence that has a major impact on the materialisation of both the PIDA and the TEN-T is the lack of sufficient public funding to reach the envisaged infrastructure levels. In addition, debt sustainability is a crucial issue, whichever continent is being considered. In the case of European national governments, their contributions to the EU budget, which in turn are invested back through the TEN-T funding instruments, is one way of achieving improved compliance with public debt and deficit requirements,[27] but it is still not enough. This is why there has been a global emergence in recent years of new financial instruments with the purpose of creating leverage of public budgets and acting as a catalyst to attract additional funding from the private sector. For instance, many public–private partnerships (PPP) have been conceived in order

25 For instance, see the activities of the Joint Africa-EU Strategy (JAES) Reference Group on Infrastructure (RGI) <https://au.int/fr/node/34309>.

26 Peters, 'Cohesion, Polycentricity, Missing Links and Bottlenecks', pp. 317–39; Aparicio, 'The Changing Decision-Making Narratives', pp. 3715–24.

27 M. Turro, *Going Trans-European: Planning and Financing Transport Networks for Europe*, Oxford, 1999, Pergamon, pp. 102–03.

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to contain public debt: the private operator contracts for a loan, while the public stakeholder pays those costs that cannot be recovered from the users directly. In practice, PPPs create fiscal risk and, in the case of Africa, low technical capacity is a major constraint to developing PPPs in fragility contexts. According to the World Bank, the global transport sector received US$636 billion in public-private investment between 1990 and 2018, and 1,861 projects reached financial closure.[28] During the same period, Sub-Saharan Africa received only US$23.7 billion across 113 projects. Private financing in Sub-Saharan Africa has mostly been channelled into the ports sector, which has seen over 50 per cent of the investment volume.

We cannot end this section without mentioning two important actors involved in the implementation of the PIDA and the TEN-T: the African Development Bank (AfDB) and the European Investment Bank (EIB). These two banks are respectively viewed as the 'African' and 'European' banks. AfDB is the lead financial institution for the PIDA and its logo appears next to those of the AU, UNECA and NEPAD in all official PIDA documents. What is more, AfDB defines itself as the 'Executing Agency' of the PIDA.[29] In the case of TEN-T's official documents, EIB is also explicitly, and almost exclusively, identified as the bank providing the loans and guarantees that complement the European budget grants. However, AfDB and EIB are neither AU nor EU institutions. EIB's shareholders are the 27 member states, and their share of the bank's capital is based on their economic weight within the EU at the time of their accession. With regard to the AfDB, 41 per cent of the shareholders and five of the top ten countries involved are non-African. In both banks, the governing statutory bodies are accountable to the shareholders, and not directly to the respective unions. This 'independence' is an aspect that is worthy of attention. Banks' strategies are driven by the credit risk of their operations and the need to keep their turnover at certain levels. The choice of projects to be financed is not always aligned with official strategies, does not appropriately respond to economic needs or does not fully integrate country debt sustainability considerations.[30] In addition, in contrast to other multilateral development banks, both the EIB and AfDB have the challenge of being dominated by their borrowers in terms of voting share.[31]

28 <https://ppi.worldbank.org/en/snapshots/rankings>.

29 <https://www.afdb.org/en/topics-and-sectors/initiatives-partnerships/programme-for-infrastructure-development-in-africa-pida> [Accessed May 2022].

30 See, for instance, the European Court of Auditors, 'Report on the European Fund for Strategic Investments', published in 2019 <https://www.eca.europa.eu/en/Pages/DocItem.aspx?did=49051>.

31 N. Birdsall, *The Dilemma of the African Development Bank: Does Governance Matter for the Long-Run Financing of the MDBs?*, Working Paper 498, Washington D.C.,

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The Current TEN–T Policy and the PIDA Priority Action Plan (PAP) for Transport: A Practical Comparison

As we mentioned in the introduction to this chapter, despite major differences between the transport systems of the two continents, there are some parallels that merit analysis. In the first place, the process for defining priority projects has evolved in similar ways. In Europe, from its initial 30 priority projects, the TEN-T has adopted a multimodal corridor approach since 2013 with a significant emphasis on regulation and non-infrastructural aspects (Map 4.3). Similarly, the definition of the transport component of the PIDA in 2012 expanded the trans-African highways concept and applied a corridor approach to transport (Map 4.2). On both continents, there is now a backbone network, the ten trans-African highways in Africa and the nine European Transport Corridors in Europe. Alongside this, there is a broader 'second layer' of transport infrastructure that in Africa is made up of the remaining 40 corridors of the ARTIN and in Europe is known as the Comprehensive Network. Next to the physical corridors, Europe also has two Horizontal Priorities – the European Rail Traffic Management System and Motorways of the Sea – themes that are also reflected in the most recent policy documents in Africa as a result of including a transport strategy in the Agenda 2063.

However, despite the official rhetoric on corridors, the first PIDA PAP still follows a patchwork approach, mode of transport by mode of transport, and lacks coherence in many cases. For instance, the creation of a tenth TAH is still not reflected in some official documents and, in the PIDA database, many projects are placed under programmes labelled as 'multimodal transport corridor', but this denomination does not correspond to a specific TAH, as in the case of the Abidjan–Ouagadougou–Bamako Multimodal Transport Corridor. In fact, considerable doubt arises where in several AU documents there is a differentiation between the TAH and the (new) African Integrated High Speed Railway Network (AIHSRN). In short, while African institutions do not clearly differentiate between the transport corridor and the transport mode, the EU has reached a consensus about the notion of corridor. We should also recall here that in the case of Europe this approach was to a large extent adopted thanks to the reinforced competences that have been transferred to the European Commission, in particular to CINEA.

As a consequence of this diverse interpretation of the notion of the transport corridor in Africa, it is difficult to compare the current TEN-T and PIDA in

2018, pp. 1–5 <https://www.cgdev.org/sites/default/files/dilemma-afdb-does-governance-matter-long-run-financing-mdbs.pdf>.

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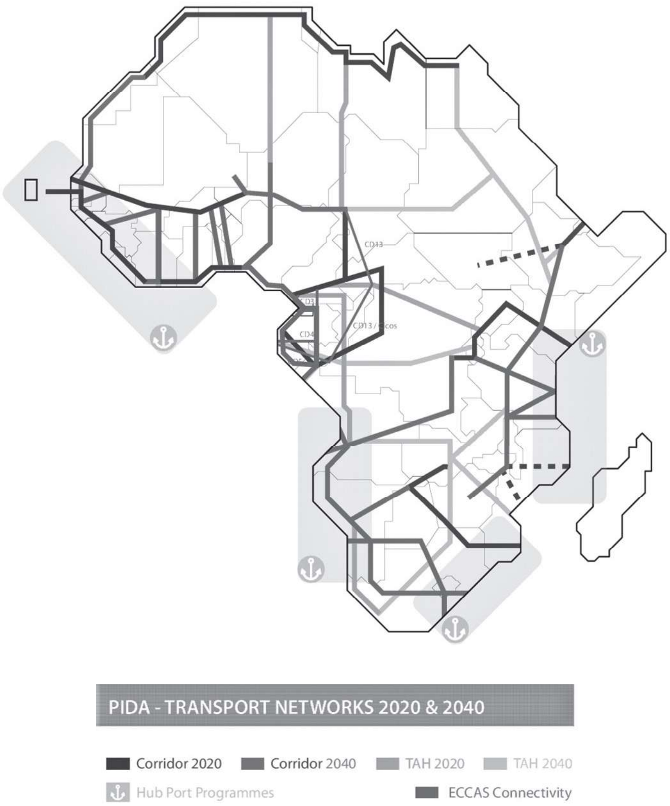
terms of investment. However, we can compare the 30 priority projects planned for 2020 in Europe with the first PIDA PAP, which was effective until 2020. As we have said, the 30 priority projects have been replaced by a corridor approach since 2013, but they are still a valid point of reference for gaining a greater appreciation of the order of magnitude of the investment in both continents. The 231 PIDA transport projects can be grouped into 24 programmes whose



Map 4.2. The transport networks to be supported by the first PIDA PAP by 2020 and 2040.
(Source: African Union 2011. Programme for Infrastructure Development in Africa. (2012). Interconnecting, integrating and transforming a continent, Addis Ababa, African Union, www.afdb.org/fileadmin/uploads/afdb/Documents/Project-and-Operations/PIDA%20note%20English%20for%20web%200208.pdf.)

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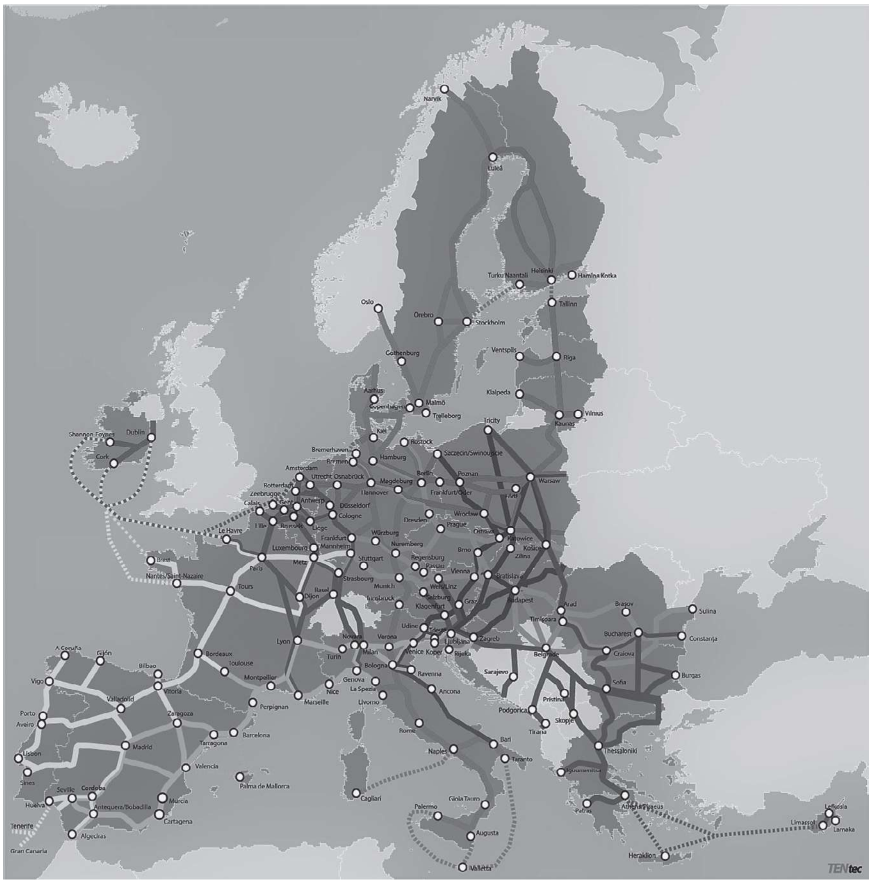

Map 4.3. European Transport Corridors of the TEN-T as revised in 2021. (Source: European Commission (2021), Creating a green and efficient Trans-European Transport Network, Factsheet, https://ec.europa.eu/commission/presscorner/detail/en/ip_21_6776.)

scale is comparable to that of the 30 European priority projects.[32] Taking into consideration the fact that the TEN-T priority projects were conceived to be implemented over 25 years and the PIDA-PAP is an eight-year plan, we can

32 <https://www.au-pida.org/pida-projects/>. There are discrepancies in some official documents. For instance, the PIDA Week 2018 concept note mentions 235 projects grouped under 25 programmes.

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estimate that in Europe, yearly investments have reached about €16 billion, while in Africa the investment is supposed to have been around €10 billion per year (see Table 4.1). The average size of a project/programme is close to €530 million in Europe and €416 million in Africa.

Table 4.1 TEN-T and PIDA PAP 1 transport priority projects.

	TEN-T 30 priority projects	PIDA-PAP 1 transport
Budget period	1995–2020	2012–2020
Overall investment	€398,340,000,000	€79,927,863,636
Investment per year	€15,933,600,000	€9,990,982,955
Number of priority projects	30	24
Investment per project	€531,120,000	€416,290,956
Total length – Priority projects (km)	47,882	62,000
Rail	*33,698*	*29,500*
Road	*10,691*	*32,500*
International waterways	*3,493*	*Not mentioned*

Sources: Programme for Infrastructure Development in Africa, <www.au-pida.org/pida-projects/> [Accessed 23 February 2022]; €1 = US$1.1.

More recently, it has been estimated in Europe that by 2030 the financial investment required for the completion of the TEN-T Core Network Corridor alone is €21 billion a year, or a total of approximately €750 billion of investment over 35 years. In Africa, the AfDB[33] estimates that transport infrastructure development requires between €31 billion and €42 billion annually. These amounts include both the PIDA and national needs. If we take into account the fact that yearly disbursements oscillate between €22 billion and €31 billion, the financing gap may be more than €10 billion, depending on the year. However, two important points arise when placing African investment needs and Europe's requirements for the TEN-T side by side. The former is related to the baseline for the calculation of infrastructure deficit in Africa. While the order of magnitude of financing needs declared in official documents may be comparable, Africa basically has two objectives: interconnecting capitals, ports, border crossings and secondary cities with a good quality road network; and

33 African Development Bank, *African Economic Outlook 2018*, 2018, p. 70 <www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/African_Economic_Outlook_2018_-_EN.pdf>.

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providing all-seasons road access in rural areas. As we have said, the priority is to provide full connectedness or *connexité*. At the same time, improved connectivity through multimodal systems (for example, high speed railways) is acquiring space on political agendas, which means that the threshold for estimating the infrastructure gap will be raised, and funding needs will increase. Secondly, in Africa, the operation, maintenance and rehabilitation costs of preserving the investments are estimated to be 80 per cent of total investment needs, and only 20 per cent is allocated to upgrading and new construction.[34] The problem in Africa is that the notion of *connexité* is very frequently breached because of a lack of maintenance and road protection. This means that, in addition to missing links, there are links that 'disappear' and need to be rebuilt several times. In short, it is very difficult for Africa to begin investing in improved connectivity when basic *connexité* is not guaranteed.

Conclusions

Among all the policies and programmes undertaken by the AU, transport is one of the sectors in which it can first engage in order to strengthen continental integration. This may seem paradoxical, since the internal market is not large enough to justify many of the international links. At the same time, it is claimed that interconnecting the continent will boost commercial exchanges, another assumption that should be made cautiously. On this point, it is not advisable to establish parallels between transport policies in Europe and Africa. Transport infrastructure is tangible and politically attractive, and can act as a catalyst for pan-African integration, but this process should in all cases be begun between densely-populated nearby territories that have the capacity to constitute a market.

The TEN-T's planning and implementation modalities have evolved significantly over time, but the various institutional arrangements have not been exempt from criticism. In particular, national and special interests seem to have prevailed in the selection of a number of projects, a circumstance that has been favoured by deficiencies in the evaluation methods. As we have seen, inadequate cost–benefit analyses or poor environmental impact assessments have contributed to the choice of projects whose added value has been exaggerated. Nevertheless, the corridor approach adopted for the TEN-T in recent years allows for a more coherent and participative framework in which governance

34 African Development Bank, *African Economic Outlook 2018*, p. 70.

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involving an important number of stakeholders is clearer, and the territorial impact better delimited.

In Africa, it is difficult to implement a similar corridor approach because of the problems associated with connectedness or *connexité*. In this case, the narrative of 'missing links' is still a valid one, provided that these links connect points with minimum density levels. The impact of a two-lane asphalt road connecting urban centres, which might seem marginal in advanced economies, may have significant structuring effects in developing countries.[35] At the same time, we have raised the question of whether full *connexité* must be achieved at all costs, and whether it is more urgent than improving connectivity between nodes where considerable levels of exchange already exist. In this respect, appropriate planning tools, as well as a broadly participatory approach, are needed to guide the decision-making process. Since reinforcement of the networks needs to focus on places where there is a sufficient population and the systems of the cities are structured, the PIDA should prioritise interventions in those territories with the highest density levels, such as the north of Africa, West African countries and the region along the Indian Ocean (see Map 4.4).

Expanding the notion of corridors and moving away from the patchwork method, as has been the case in Europe, would be fundamental for increasing transparency, better defining the scope of decisions and specifying the appropriate level where they should be adopted. A sustainable and harmonious development of African transport networks is exposed to threats similar to those identified in Europe. However, because Africa suffers from meagre public budgets and a maintenance backlog, every effort should be made to avoid the proliferation of 'white elephants'. In this regard, it is essential that corridor approaches should first target the consolidation of territories with a sufficient network density.

Since the AU does not have funding of its own to develop the network, it lacks the capacity to incentivise better planning instruments. In addition, readily available funds without significant social and environmental safeguards make it particularly difficult for African countries to abstain from accepting offers of aid from certain partners, notably China. These external interests, which are often driven by mining industries, find support among political and financial elites and prevent a thorough analysis to determine whether the overall conditions of a particular deal are favourable for the country.

One asset the AU possesses, which does not exist in Europe, is the existence of RECs, and current PIDA implementation relies heavily on them. The

35 B. Steck, 'Transport et Développement', in M. Brocard (ed.), *Transports et Territoires. Enjeux et Débats*, Paris, 2009, pp. 125–55.

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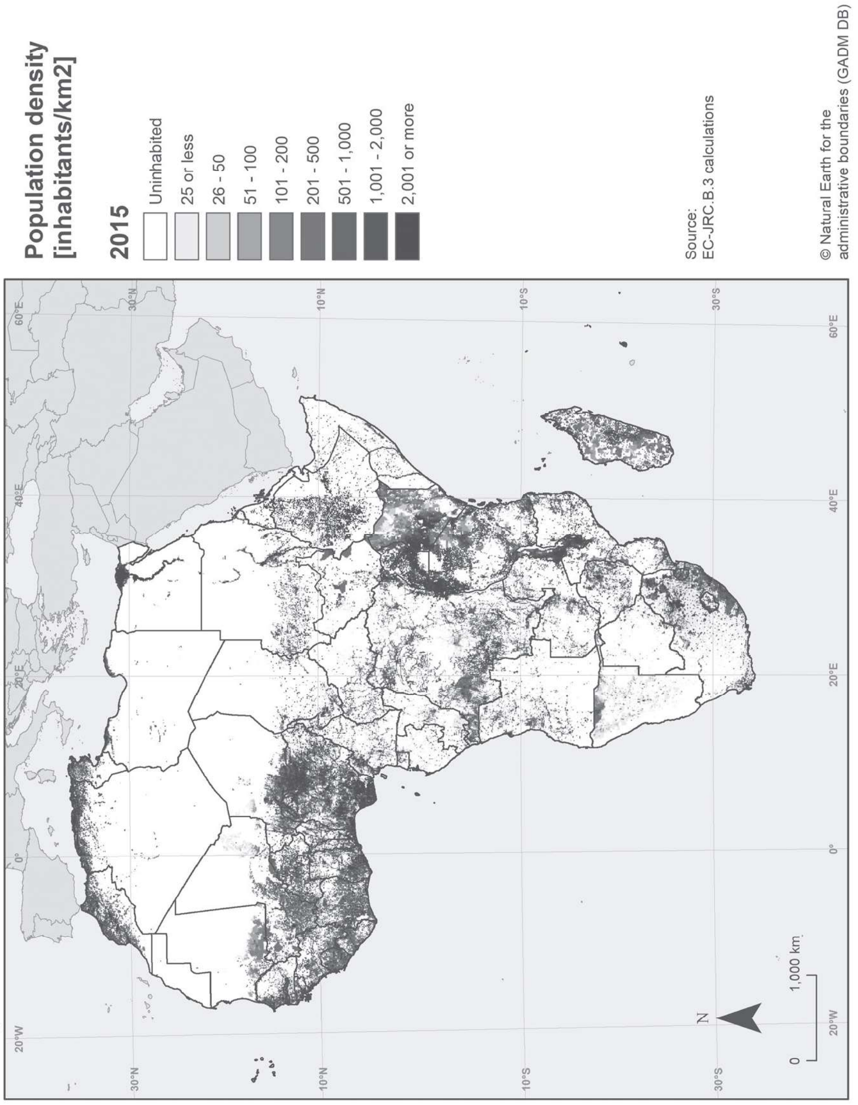

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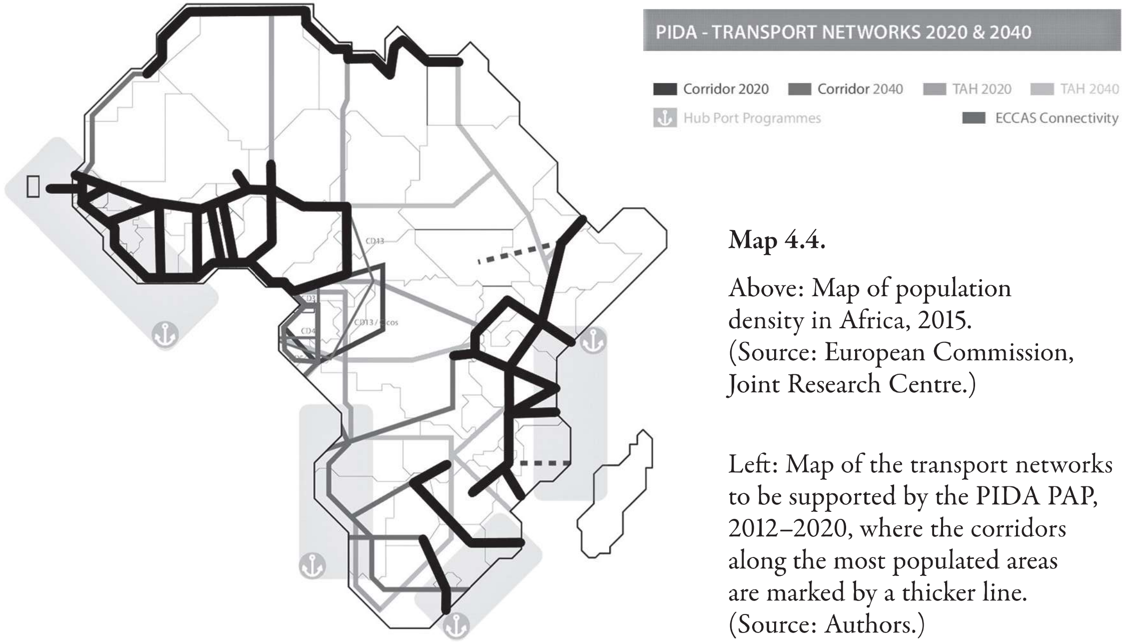

Map 4.4.

Above: Map of population density in Africa, 2015. (Source: European Commission, Joint Research Centre.)

Left: Map of the transport networks to be supported by the PIDA PAP, 2012–2020, where the corridors along the most populated areas are marked by a thicker line. (Source: Authors.)

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establishment of African transport networks should continue to be supported by this intermediate level. At the same time, the AU should rationalise its project preparation facilities and keep the focus on building the capacity of its member states to plan and implement infrastructure projects. The second PIDA PAP will present a good opportunity for addressing these issues.

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Patchwork in an interconnected world: the challenges of transport networks in Sub-Saharan Africa

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Patchwork in an interconnected world: the challenges of transport networks in Sub-Saharan Africa*

Sergio Oliete Josa [a] and Francesc Magrinyà [b]

[a]Directorate General for International Cooperation and Development, European Commission, Brussels, Belgium; [b]Departament d'Enginyeria Civil i Ambiental, Universitat Politècnica de Catalunya, Barcelona, Spain

ABSTRACT
Sub-Saharan Africa has recently undergone, or still do in many countries, a period of transport infrastructure expansion. Current policies are centred on the development of international links, which require large capital-intensive projects and are sometimes economically dubious. This paper reviews the past policies and transport functions since colonial times by placing them in their economic and political context. We find that present strategies have similarities to the ones prevailing in previous periods, where expansion phases dominated by transport-led economic growth theories were followed by a stagnation of Africa's infrastructure development. In view of the challenges in translating findings from empirical research into right policies, we identify the potential of more balanced and sustainable strategic investments, notably by reinforcing the existing secondary transport networks converging into urban centres.

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Transport; road; rail; infrastructure; Africa; development

1. Introduction: the myth of the transport-led economic development in the African context

In 2009, the 12th Assembly of the African Union adopted a Declaration inviting the African Union Commission to formulate the Programme for Infrastructure Development in Africa [PIDA] (African Union, 2009). In this Declaration, the Heads of State and Government, concerned about "the enormity of gaps in transport and energy infrastructure in Africa and the huge financing needs of these infrastructure", decided to "take all appropriate measures to complete the missing sections in the major transport corridors and remove all physical and non-physical barriers to the development of inter-State transport in Africa". The expected impacts of PIDA in the transport sector are to "link the major production and consumption centres, provide connectivity among the major cities, define the best hub ports and railway routes and open the land-locked countries to improved regional and continental trade" (PIDA, 2012). If the completion of transport corridors is so critical, why does Africa not yet have a complete continental transport network? The map of the transport network

CONTACT Sergio Oliete Josa sergio.oliete-josa@ec.europa.eu Directorate General for International Cooperation and Development, European Commission, Rue de la Loi 41, B-1049, Brussels, Belgium
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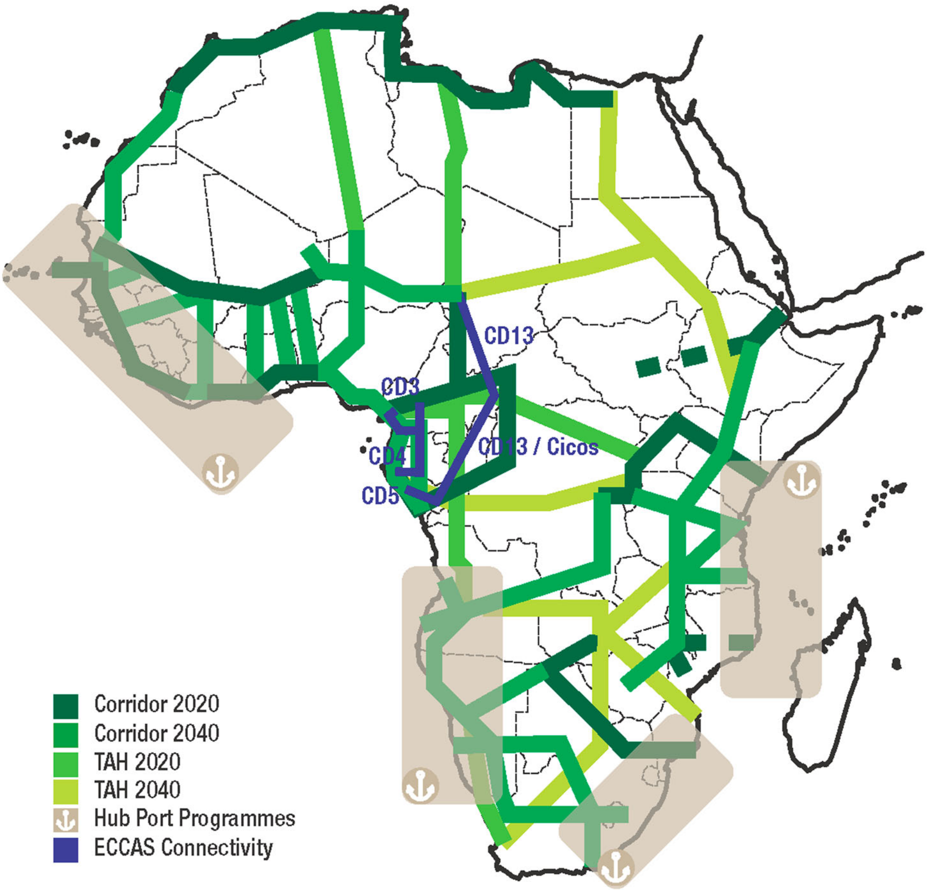

Figure 1. PIDA's transport network plan (PIDA, 2012). [TAH: Trans-African Highway].

proposed by the PIDA (Figure 1) shows that some of these corridors connect Africa from north to south and from east to west, going through the Saharan region and the Central African forests; other corridors open landlocked countries; a third category, mostly parallel to the coast, links capitals and main port cities to each other.[1]

These political statements inevitably raise the question of the growth-enhancing effects of transport infrastructure in the African continent, or the "effets structurants" as this supposed causality relationship is known in the francophone literature. In 1993, Offner had evidenced the methodological deficiencies of the ex-ante studies used by decision-makers to justify major transport projects. He argued that a transport facility does not necessarily generate new economic value, but rather accelerates or consolidates the pre-existing dynamics and trends (Offner, 1993). The construction of a new transport infrastructure will only generate growth if there is a concomitance of mutually supported politico-institutional, economic and investment conditions (Banister & Berechman, 2003). The economic effects of new transport infrastructure are not obvious in industrialised countries, where networks are dense with high traffic flows intense, and decision-making based on econometric models remains controversial (Deng, 2013). On the contrary, in underdeveloped contexts, transport infrastructure can be a direct and crucial factor of territorialisation (Steck, 2009). However, in developing countries, policy formulation based on empirical evidence may even be more difficult due to lack of quality data (Berg, Deichmann, Liu, & Selod, 2017; Calderón & Servén, 2014) and, in the case of Sub-Saharan Africa, to the existence of strong political-economy constraints (Beuran, Gachassin, & Raballand, 2015).

The purpose of this paper is to contribute to transport policies in Sub-Saharan Africa by analysing, from a geo-historical perspective, the development of the transport networks since colonial times and the place of the current policies in this evolution. We are interested in seeing to what extent infrastructure-led development theories have been influent at different points and to what extent previous experiences are currently being taken into account. This paper reviews the different approaches and ideologies that have underpinned the development of the transport infrastructure since the construction of the first railways and roads in Sub-Saharan Africa. Our hypothesis is that, once historical reasons leading to network failures are properly identified, patterns followed by African transport systems replicate models comparable to others contexts, particularly with regard to the critical role of urban hierarchies and the regional influence of cities.

In Section 2, a timeline with the principal events and different identified periods is proposed and commented upon. While we study the evolution of transport networks in Sub-Saharan Africa at continental level, many of the specific cases used to support the review focus on West and Central Africa. Section 3 presents the recent relevant literature to show that typical methodological limitations of research on transport and development amplify in the case of Sub-Saharan Africa and that empirical evidence does not necessarily translate into appropriate policies. Section 4 identifies the potential of tackling more resolutely the development of secondary networks converging into cities. Section 5 concludes and provides some policy recommendations.

2. The cyclical pattern of transport infrastructure policies in Sub-Saharan Africa

In the past, the gradual development of transport networks in Sub-Saharan Africa has been closely related to the construction of the national territories (Lombard & Ninot, 2010). This evolution was determined by the initial decisions taken during the colonial period and, afterwards, by the political will of the newly created states. Almost 60 years of international aid since the first independences has also had a significant impact in shaping African transport networks. A review of the development of the land transport networks in Sub-Saharan Africa is summarised in Figure 2. On the basis of the works of Debrie (2010), three main geo-historical periods are distinguished: the colonial, the national and the regional. This timeline includes a bar chart where we have indicated the periods of expansion and stagnation of transport infrastructure. This framing is superposed to the ideal-typical sequence of transport development proposed in 1963 by Taaffe, Morrill and Gould. The length of these periods is indicative; the relative infrastructure growth of each period is not based on quantitative calculations, but on this paper's review of literature and documents. In most countries, these cycles have not generally implied a contraction because the lifespan of transport infrastructure is long enough. That is the reason why we prefer to use the word "stagnation". The exception to this irreversibility is countries that have undergone a major crisis, like a war, hastening the degradation of roads and rails and/or causing

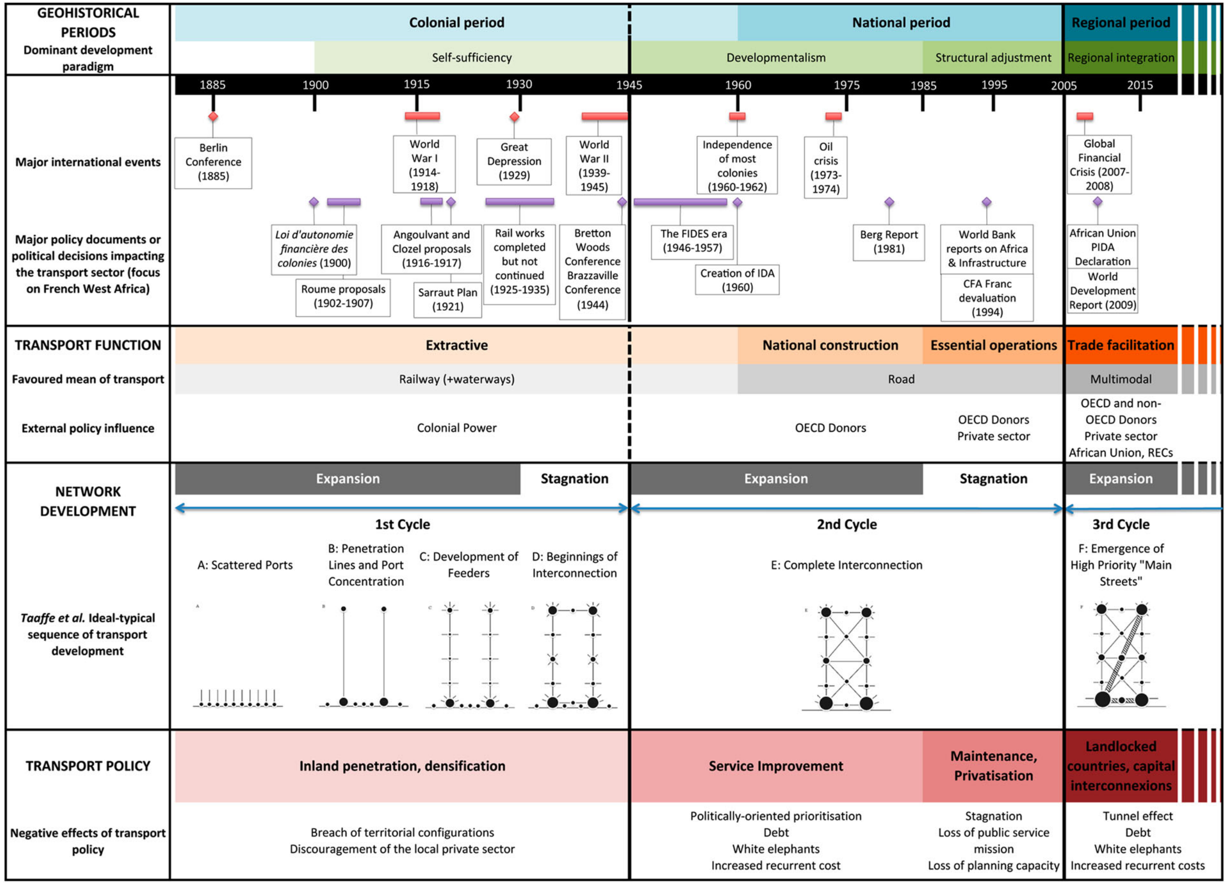

Figure 2. Evolution of the transport networks in Sub-Saharan Africa: an explanatory timeline.

the abandon of maintenance programmes. A description of these growth-decline cycles is provided in the following four sub-sections.

2.1. Colonial and geographical determinants

In the early stages of colonial rule, the penetration transport lines were essentially built for geopolitical reasons and military control and to connect the seacoast with the hinterland, thus enabling the export of minerals and agricultural products to the metropolitan countries (Taaffe, Morrill, & Gould, 1963). The initial plans of colonial powers were rather ambitious, especially in French West Africa where successive colonial governors projected transcontinental rail networks aiming to connect the main ports to all inland major cities (Debrie, 2001). They even proposed to exchange territories with the British Empire in order to obtain a more logical territory and coherent transport network (Marguerat, 1997). However, this initial expansion was significantly limited by economic constraints. In 1900, France passed a law adopting the principle of the financial autonomy of the colonies. For colonial powers, capital investments were justified, at first, to access areas with high economic value. The prevailing principle was that colonies had to be self-sufficient, with minimal administration (Young, 1994). Europeans wanted to maximise profits from colonies at the least possible cost (Njoh, 1997). For Taaffe et al., mineral exploitation was the main reason for the rail penetration, as it allowed for repayment of the loans required to finance the infrastructure. Njoh highlights the preference of colonial governments to develop interregional rather than intraregional links and observes that these lines were also conceived to facilitate the transport of labour from inland to the coastal plantations. In the words of Debrie (2010), this period was characterised by "the primacy of economic considerations and the absence of a political plan". As a consequence, colonial territories had an uneven infrastructure provision, and the transport network covered only a limited space within the colonial boundaries. As a matter of fact, the existing transport discontinuities in distant regions were seen as administrative divisions of the colonial space (Herbst, 2000), and when the independences were declared, some of these undeserved areas delineated the national borders of the new states (Debrie, 2010). In the 1960s, Taaffe et al. already raised the alert that vast areas of the new created African countries, mostly in the periphery, remained inaccessible by road or rail.

Major disparities in infrastructure provisions were just one of the consequences of a more complex effect of the colonial heritage on the future development of transport networks. Graham and Marvin (2001) note that colonial authorities paid little attention to the mobility needs of local populations. As these authors suggest, "traditional modes of transport were often undermined by new rail and road networks, substantially disadvantaging many important indigenous towns that were economically and administratively bypassed". Colonial powers enforced bureaucratic obstacles to the development of local industries, and controlled the economy by diverting trade through coastal cities, which was more favourable to the colonialist (Graham and Marvin 2001). This originated the decline of many pre-colonial prominent towns and accelerated the growth of others, particularly the ones that became colonial administrative centres (Njoh, 2006). Some contemporary major African cities did not even exist before colonial times. This reshaping triggered the first significant flows of modern rural–urban migration in Sub-Saharan Africa (Stren & Halfani, 2001). The development of transport networks in Africa entailed the destruction of previous territorial configurations and the establishment of new spatial compositions (Steck, 2009). Slater (1975) described it as "a simultaneous process of internal disintegration and external reintegration". For Debrie (2001), these mechanisms have led to territorial inversions. Centralities have changed due to physical and administrative discontinuities in the networks. As a consequence, continental areas, such as the Sahel, which once were central to trade, are now considered landlocked. Conversely, coastal areas became central to trade because maritime transport was key to the expansion of the colonial empires.

When looking at the influence of colonial intervention in the evolution of transport networks in Africa, the role of physical geography cannot be underestimated. Colonisers were confronted with an adverse environment that today still has an effect on economic development (Gallup, Sachs & Mellinger, 1999). A critical factor was tropical climate, which is favourable to the vectors of transmission of infectious diseases. Acemoglu, Robinson and Johnson (2003) recall that mortal diseases such as malaria and yellow fever made many colonised areas forbidding to Europeans, circumstance that affected the institutional development and has subsequently constrained the economic development. Gallup et al. also stress the correlation between a hot, extreme climate – humid or dry – and the low productivity of agriculture.

Yet, unfavourable geography negatively affects African economic development in several other ways. As Adam Smith already noted in 1776, Africa lacks navigable rivers providing access from the interior to the sea, and the largest ones are too distant from each other. The rough relief of Africa is linked to higher investment costs in agriculture, construction and transport (Naudé, 2009), although historically ruggedness has also been advantageous in protecting local populations from slave trade (Nunn & Puga, 2012). Furthermore, on what Naudé calls second-nature and third-nature geography,[2] Sub-Saharan Africa suffers from three drawbacks: low densities, long distances and deep divisions (World Bank, 2009b). Many traditional pre-colonial settlements were dispersed and located away from the sea. In the Middle Age, the nexus between the expansion of Islam and trade favoured the urbanisation along fertile areas of the Southern limit of the Sahara, like the Lake Chad shores or the Niger course (Bairoch, 1985).[3] Meanwhile, there has been a significant increase of urbanisation around the world, multiplying by five the urban population between 1930 and 1970. However, following independence, Sub-Saharan Africa still had rates of urbanisation below 15%, and cities were of small size in general (Bairoch, 1985). A major consequence of this population distribution pattern was that colonial governments were unable to collect significant taxes from individuals and opted to rely essentially on custom duties (Herbst, 2000). At the end of this period, the partition of the African colonies into "artificial states" fragmented the territory and exacerbated pre-existing geographical hindrances (Alesina, Easterly, & Matuszeski, 2011).

2.2. The national construction: governments' failure to meet expectations

As represented in the second row of Figure 2, between the Second World War and the final years of colonialism, self-sufficiency policies had been progressively replaced by a developmentalist vision (Young, 1994). This new doctrine implied vast amounts of public investment, especially in infrastructure projects, and the spending of savings accumulated over previous decades (Herbst, 2000). This boost should be understood in reaction to the strategic role that African colonies had played in the war and in the context of the threat of the Cold War. In the case of West Africa, Huillery (2014) provides quantitative evidence showing that post-war policies represented an important increase of funding to develop infrastructure. These investments essentially consisted of loans channelled through the French "Fonds d'Investissement pour le Développement Economique et Social (FIDES)", created in 1946.

The aftermath of the Second World War also favoured the resurgence of Eurafrican ideals. The creation of a homogeneous and coherent transport system between Europe and Africa, including the realisation of the trans-Saharan railway from the Mediterranean to the Niger River, was seen as a precondition to establishing the Eurafrica region (Guernier, 1957). In spite of failing to receive an official endorsement (Dramé & Saul, 2004), these ideals had a decisive influence on the Yaoundé Convention signed in 1963, which defined the principles of the multilateral association between Africa and Europe (Hansen & Jonsson, 2014) that, since then, has contributed to finance a significant part of African transport infrastructure.

African independences coincided with the emergence of the "big push" thesis, which proposed accelerating the growth of underdeveloped countries. As a result of the extractive colonial policies, economies of the independent countries had been born deficiently industrialised and highly dependent on export-oriented resources (Herbst, 2000). The new political leaders, in a conjunction of pragmatism, lack of capacity and desire to preserve their privileges, readily adopted the pre-existing economic model, allowing for the emergence of "rentier states", where the vast majority of the revenues derived from the rent of natural resources to foreign interests (Clapham, 1996). As a consequence of the deficiencies of the inherited fiscal system, the revenue structure of African countries centred almost exclusively on custom duties and foreign aid (United Nations Economic Commission for Africa [UN-ECA], 1967).

At the end of the 1950s, influential economists like W. Rostow and Rosenstein-Rodan pleaded for massive foreign aid rather than relying on the scarce local savings. They urged support for central governments with substantial international aid programmes in order to simultaneously stimulate investments in several economic sectors (Rosenstein-Rodan, 1961). The big push was supposed to overcome the poor absorption capacity and to increase the national revenue and the size of internal markets. This model was deemed as appropriate for Africa. Colonial policies had had the final consequence of virtually dismantling the local private sector, and Western countries continued to look down on its entrepreneurial capacity (Herbst, 2000). Despite frequent criticisms, particularly on the lack of qualified human resources and institutional capacity of low-income countries to absorb large amounts of foreign aid (Adler, 1965; Myint, 1969), the World Bank predominantly adopted this model in Africa because the new states were seen as an opportunity to expand its lending activities (Fisette, 1997). In 1960, faced with the prospect of the insolvency of a number of African states, donor countries set up the International Development Association (IDA) and entrusted the World Bank with its execution (Laïdi, 1989)[4]. Between 1961 and 1965, 76.8% of all World Bank loans and 50% of IDA loans were granted in the transport and energy sector (Ayres, 1983).

In spite of capital inflows in the form of foreign aid, and the enormous revenue potential from cash-crop agriculture and mineral extraction, most independent Africa states

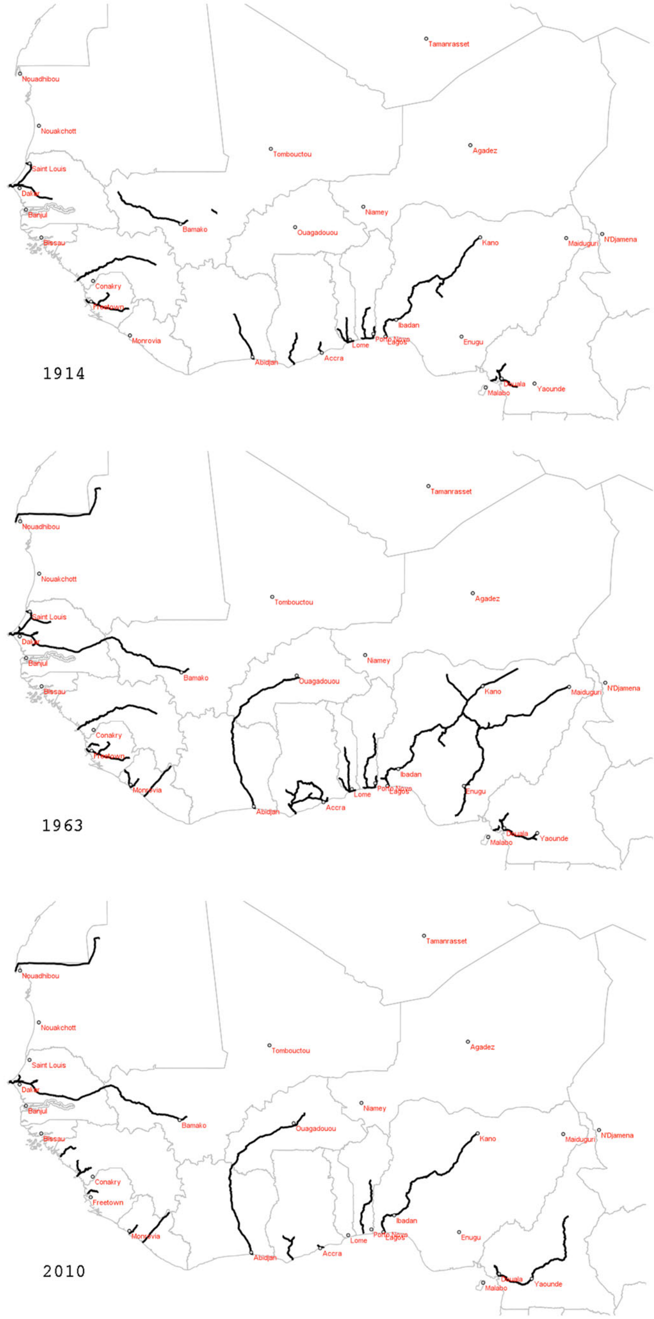

Figure 3. Rail lines in service in West Africa in 1914, 1963 and 2010.

quickly entered into a spiral of indebtedness and slow growth. In an attempt to compensate for structural and geographical weaknesses, African rulers adopted development policies that exacerbated the economic problems (Clapham, 1996). In particular, road transport, a symbol of sovereignty and unity and of territorial control, attesting the very existence of the new nation on the African scene (Debrie, 2010), had become an attractive sector that favoured the proliferation of "white elephants" (Robinson & Torvik, 2005). Public resources of African countries did not follow the substantial increase of public expenditure and were not appropriately oriented (UN-ECA, 1967). For instance, more public expenditure of low-income African countries was on infrastructure than on productive activities, education and social protection (UN-ECA, 1967). The conviction of a rapid launch on the basis of monetary injection, "the big push", entailed the implementation of inadequate urban-centred industrialisation policies. In 1977, Lipton and other development theorists warned of an "urban bias" in developing countries' governmental actions. In their opinion, an economy based on heavy taxation of agricultural exports, that diverts resources to industry and urban development, is not viable and condemns rural populations to permanent poverty. Pedersen (2003) emphasises that these import-substitution policies allowed for a further progress of capital cities and main ports, but did not contribute to the national economic integration or to the development of the national transport systems. Actually, transport policies were not a break with the previous period but rather a continuation of the policies decided by the colonial powers (Lombard & Ninot, 2010).

From the 1970s, the increase in the number of asphalted roads represented a harsh competition for the railway mode, which ended by putting the relatively good-performing rail public operators into financial troubles (Chaléard & Chanson-Jabeur, 2006). This precipitated the decline of small hubs and towns situated along the rail lines, where the large colonial trading companies were established, while other towns expanded due to their positioning on the new roads (Lombard & Ninot, 2010). As it is shown in Figure 3, with the exception of Cameroon and some private mining lines, the railway network in West Africa has contracted since the 1960s and it is still far from reaching the connectivity aspired by colonial powers and current governments.

2.3. The deregulation of the economy and the power of the World Bank's policies (1985–2005)

At the end of the 1970s, a widespread debt crisis accompanied by very low, or even negative, growth rates had emerged in Africa (UN-ECA, 1980). In addition to the structural and inappropriate policies, the international economic situation, notably since the oil and stock market crisis of 1973–1975, contributed to aggravate the African development problems. The reasons for the poor economic performance of Sub-Saharan countries were detailed in a 1981 World Bank report known as the Berg Report. This report proposed a new strategy to rectify the existing situation by identifying "major policy actions central to any growth-oriented programme: more suitable trade and exchange rate policies; increased efficiency of resource use in the public sector; and improvement in agricultural policies". The Berg Report positioned the World Bank as the "dominant source of economic and policy analysis for Sub-Saharan Africa" (Sander, 2002) and became the "immediate intellectual precursor to the introduction of the structural adjustment programmes (SAPs)" (Mkandawire & Soludo, 1998) largely assumed in the 1980s by international financial institutions, bilateral donors and governments in Africa.

SAPs were instituted to encourage higher growth rates in countries experiencing economic crises. For this purpose, African governments were asked to undertake promarket reforms, notably through macroeconomic measures, domestic deregulation, trade liberalisation, civil service reform and privatisation of public enterprises (World Bank, 1994a). These policies affected the transport sector in different ways. First, adjustment measures resulted in a substantial reduction in infrastructure capital spending (World Bank, 1994b). This contracted the already scarce resources allocated to road maintenance, and consequently, roads in Africa entered into an irremediable deterioration process (Torres Martinez, 2001). In 1988, Sub-Saharan countries had lost 15% of the capital invested in main roads, or approximately 3.3% of GNP, due to lack of maintenance (Harral & Faiz, 1988). The same year, less than 50% of Sub-Saharan Africa's paved roads were in good condition, with countries like Ghana, Cameroon and Mozambique having only 28%, 38% and 10%, respectively, of paved roads in good condition (World Bank, 1994b). The Harral and Faiz study concluded that, in a number of African states, it would have not been possible to rehabilitate the network within a period of ten years, even if funding had been increased by 50% and new construction held to 20% of the new total to ensure adequate maintenance. In 1994, the proportion of roads needing restoration had increased to one-third, having a cost estimated at $13 billion; in parallel, the portion of IDA commitments allocated to infrastructure had been reduced to one-third of the total, that is, $2 billion per year (World Bank, 1994b). During the period 1985–1994, IDA commitments for transport in Africa amounted to approximately $3.6 billion of a total of the $14.5 billion allocated to the sector by Official Development Assistance (ODA) donors (Torres Martinez, 2001). In addition to these financial constraints, factors that accelerated road degradation include traffic growth, absence of protection against overloaded trucks and weak technical and managerial capacity in the road maintenance departments (European Commission, 1991). In this context, African rail operators had also been particularly impacted, as they had entered into a vicious circle of decay: low traffic due to the economic crisis and road competition, drop in revenues, high debts that governments were not able to subsidise, stricter donors' conditions, lack of maintenance, operational failures, customers' dissatisfaction and lower revenues (Dupre La Tour, 2006).

From the mid-1980s and during the 1990s, in view of the importance of transport to economic development, Transport Sector Projects (TSPs) were progressively introduced in Africa. TSPs were closely linked to the economic reforms promoted by the SAPs and led to profound institutional changes in the transport sector (Adolehoume, 1999). Considering the high transport costs, the low efficiency of the public companies and the deplorable situation of the road network in Africa, TSPs mainly focused on two aspects: to liberalise transport services and to improve road maintenance (Adolehoume, 1999). For these purposes, the prevailing formula prescribed by the World Bank was to increase the involvement of the private sector (World Bank, 1994b) and to redefine the role of the government (World Bank, 1996). These policies resulted in the privatisation of many national and international public transport enterprises and facilities such as rail lines, truck companies and container terminals. The segmentation of the sector management increased financial efficiency but entailed a loss in coherence and long-term vision (Lombard & Ninot, 2010). With regard to road maintenance, public works departments were restructured and limited their roles to tendering, managing and supervising work contracts instead of carrying out direct operations (Adolehoume, 1999). A major reform was the introduction of second-generation Road Maintenance

Funds (RMF), based on the idea that "commercialising" road management would secure and increase the efficiency in the use of the funds (Heggie, 1995).[5] However, benefits expected from TSPs take a long time to become a reality. RMFs still perform with difficulties in many countries (Foster & Briceño-Garmendia, 2010). In West and Central Africa, the CFA Franc devaluation in 1994 accelerated the fragmentation of the transport offer by a multiplication of informal road operators who overload and use old trucks in poor condition to make their investments profitable (Debrie, 2001). In West Africa, the absence of a real regional integration still favours unfair competition between corridors and prevents the implementation of a coherent truck-load control policy (Zerelli & Cook, 2010).

The period of hegemony of SAPs coincided with significant developments of the transport sector at the international level, in particular the containerisation and the concentration of the shipping industry (Pedersen, 2001). These private strategies had little immediate impact in the African transport configuration because of limited port capacity, predominance of unskilled low-wage professionals and deficient inland transport conditions (Pedersen, 2001). However, the development of the most vital logistical chains for the national economy started to be strongly influenced by these private international interests (Debrie, 2001). Indeed, as a result of the privatisation and deregulation process, only the most promising and profitable terminals, lines and services had actually been conceded and awarded to a few big logistic groups (Chaléard & Chanson-Jabeur, 2006). In addition, these international companies base their business models on monopolistic practices aimed at offering the full range of activities of integrated door-to-door services in specific international corridors (Debrie, 2001).

In terms of network development, the end of the national period was strongly impacted by SAPs, a phase of stagnation as labelled in Figure 2. The density and the technical nature of the transport network had virtually not changed (Debrie, 2010). Priority had been given to rehabilitating the existing infrastructure. IBRD/IDA commitments for transport in Africa remained below $600 million per year between 1995 and 2006, representing 14% of the total IBRD/IDA commitments in the region (World Bank, 2007). The financial volumes of European aid in the form of grants to the sector were of the same order of magnitude during this period, between €400 and €500 million per year (European Commission, 2008). As a point of comparison, in 2008, the annual spending needs for the transport sector in Sub-Saharan Africa were estimated at $18.2 billion, of which $8.8 billion was required for capital expenditure and $ 9.4 billion for operation and maintenance (Foster & Briceño-Garmendia, 2010). Despite the enormous financial gap, this phase ended with "signs of a more positive development" (Pedersen, 2003) and a growth both of EDF and IBRD/IDA transport commitments, the latter "because the [World] Bank realized that excessive transport costs continue to be a hindrance to the Region's development" (World Bank, 2007).

2.4. The trade/regional integration paradigm and the inrush of Chinese interests

In the last 20 years, economists have developed areas of interest particularly relevant to understanding growth and poverty reduction in developing countries. A number of them are concerned with the specific difficult situation of Africa and study the relationship between growth, trade, transport costs, infrastructure and natural geography (Bosker &

Garretsen, 2012; Limão & Venables, 2001; Naudé, 2009; Redding & Venables, 2004; Venables, 2010). Authors have been pleading the importance of helping African countries in market liberalisation and in improving their capacity to trade, claiming the fact that trade works as leverage for economic growth and poverty reduction (Collier, 2008; Collier & Venables, 2007; Stiglitz & Charlton, 2006). The unquestionable proximity of most of these scholars with the World Bank and other development agencies has influenced policy-making in developing countries.[6] Such is the case that, since the launch of the Aid for Trade initiative at the Hong Kong Ministerial Conference in 2005, trade facilitation and regional agreements are considered as central instruments for development assistance (World Bank, 2009a; African Development Bank Group, 2013; European Commission, 2011). Another prominent development policy document influenced by economic geography theorists is the World Development Report of 2009, entitled "Reshaping Economic Geography" (World Bank, 2009b). The main assumption is that, in a given territory or country, economic production cannot be encouraged simultaneously all over. It provides evidence that the geographic concentration of economic activity will increase the national average worker productivity and incomes. The emigration of workers and firms from low-density areas will ultimately also lead to higher per capita incomes in the regions that lose population. Transport infrastructure has a notable impact on location decisions and consequences on local and aggregate incomes. The report concludes that, although growth is necessarily unbalanced across space, development can still be inclusive, thanks to the convergence of living standards.

The advance of trade and regional integration policies that has characterised this period has coexisted with a significant increase of aid to infrastructure development (Gutman, Sy, & Chattopadhyay, 2015). In 1994, bilateral and multilateral foreign aid accounted for approximately 12% of the total infrastructure financing in developing countries (World Bank, 1994b). In 2008, 25% of the capital spending on infrastructure in Sub-Saharan Africa came from ODA and non-OECD donors (Foster & Briceño-Garmendia, 2010). In 2014, 28% of the total funding for infrastructure in Africa (including North African countries) came from bilateral donors and multilateral banks (Infrastructure Consortium for Africa, 2014). It is in this context that, in 2012, the PIDA was drawn up and approved by the African Union. In addition, during this time, there has been a proliferation of publications and initiatives interested in the infrastructure financing needs at a continental level.[7] Concomitantly, OECD donors' investments in the transport sector have had a growing focus on regional economic integration, tending to finance regional multimodal corridors that interconnect African capitals and give sea access to landlocked countries (see, for instance, Ernst & Young, 2012). As Figure 2 displays, this period, where trade and regional integration becomes the archetype for African countries, has strong similarities to the sixth and last phase preconised in the Taaffe et al. model.

Another common message of recent policy documents is the importance of increasing the participation of the private sector, notably through Public–Private Partnerships (PPP), in order to fill the gap of Africa's infrastructure financing needs. However, private investments as a contribution to the total funding in infrastructure in Africa (including North African countries) have remained low, 9% in 2012 and 4% in 2014 (Infrastructure Consortium for Africa, 2014). Osei-Kyei and Chan (2016) examine the adverse institutional context to develop PPP projects in Sub-Saharan Africa, which is one of the developing regions with fewest transport PPP projects and highest number of failed ones.

Finally, a major feature in the Africa infrastructure sector in the current period is the surge of Chinese investment. Although other significant non-OECD financiers have also become relevant, China quadrupled development aid between 2001 and 2005, with a specific focus on resource-rich Sub-Saharan countries (Foster & Briceño-Garmendia, 2010). Between 2011 and 2013, the average commitments of Chinese lending to African infrastructure projects were $13.9 billion. In 2014, China contributed with almost 15% of the total financing committed for Africa's infrastructure development, including the African national budgets (Infrastructure Consortium for Africa, 2014). On average, approximately 67% of Chinese investments have been allocated to the transport sector (Infrastructure Consortium for Africa, 2014). Although Chinese investments are mostly centred on internationals links, as it is the case with ODA projects, Bonfatti and Poelhekke (2017) provide some evidence on a bias towards reinforcing Africa's interior-to-coast transport network, probably obeying to mining interests. Another aspect is the significant arrival of Chinese construction firms, not only to execute projects funded by the Chinese government but also under contracts financed by traditional partners like the World Bank or the African Development Bank. Corkin, Burke, and Davies (2008) describe the intervention of Chinese firms and the role of China in the developments of large infrastructures in Africa and highlight that the entry of Chinese companies in the Africa's construction sector has intensified competition in the bidding process.

According to these trends, the outlook of Africa's infrastructure seems favourable. Paradoxically, this growth in financing infrastructure projects has not necessarily implied better projects and reduced transport costs. Policies requiring comprehensive project appraisals, going beyond classic cost–benefit analysis, have not been consistently implemented (World Bank, 2010). High transport prices in Africa cannot merely be explained by lack of infrastructure in good conditions (Teravaninthorn & Raballand, 2009). Non-physical determinants, as customs formalities, corruption and the prevalence of transport cartels, are still highly representative in the breakdown of transport prices. In addition, recent developments suggest caution. Economic uncertainties that followed the global financial crisis of 2008 remain. After a fall in external aid, infrastructure commitments have increased again from 2011, but China's flagging economy seems to also have entailed a shift in the country's investment strategy in Africa: in 2014, Chinese commitments for infrastructure were reduced by 77%, down to $3.1 billion (Infrastructure Consortium for Africa, 2014). The overall growth in Sub-Saharan African countries is decreasing, mainly as a result of the decline in oil and other commodity prices. Security conditions have deteriorated in many places, which also has a negative impact on the economy. These adverse conditions develop in contexts that still have high levels of inequality and are unattractive for domestic and foreign investors. In response to this weakening, policy recommendations from IMF in 2015 include, among other macroeconomic and institutional measures, fostering competitiveness by "productivity-enhancing infrastructure investments while maintaining debt sustainability" (International Monetary Fund, 2015).

3. Challenges for incorporating recent empirical research recommendations into transport policies

A noticeable characteristic we can draw from the previous section with regard to the outline presented in Figure 2 is that the development of Sub-Saharan Africa's transport infrastructure may currently be at the changing point of a third cycle turning into stagnation after more than a decade of expansion. In particular, in West and Central Africa, the current situation has similarities to the big push policies of the era of the FIDES loans and the first years of independence. Since the infrastructure coverage today is much larger and of better quality, and African economies are more solid, a slowdown would probably have less critical consequences than the ones of the period of the 1970s–1990s. However, as it is explained, current policies represent significant investments, the rise of public debt and an increase in operational and maintenance costs, circumstances that may lead to another period of inactivity, infrastructure degradation and the abandonment of important projects.

As can also be observed in Figure 2, each of these three cycles shows a correspondence between the rise of Africa's infrastructure financing and the proliferation of studies and policy documents advocating for it. It should be clarified though that the succession of growth theories or the set of paradigms in development strategy thinking that has evolved over time is not as disjoint as Figure 2 may suggest. For instance, the "big push" thinking contained the element of emphasising increasing returns to scale or indivisibilities of inputs that is fundamental for the current development thinking. Large-scale (indivisible) investment is supposed to have a coordinating effect for private investors, leading to cumulative causation of development as average costs of infrastructure services or manufacturing production decrease with increasing demand. This is expected to secularly increase macroeconomic productivity. Similarly, the importance of access to local and international markets had not been suspended in the early days of development policies.

The effects of transport infrastructure and their theoretical justifications in the Sub-Saharan context remain controversial and easily misconceived. Retrospectively, some authors consider that forced and violent opening of inland areas during colonial times cannot be considered as a development policy (Steck, 2009) and even resulted in under-development and poverty in the case of Southern Africa (Pirie, 1982). This adverse effect of transport networks is also identified in the post-colonial periods. Debrie (2001) rightly notes that aid projects opening landlocked areas often adhere to a strictly technical vision. Certain corridors are privileged, but the interaction between the network and the territory it crosses is ignored. There is a polarisation effect, where a small number of urban centres and main corridors have a growing hegemony to the detriment of the rest of the country (Péguy, 1998). The concentration of the flow in a few corridors may lead to the emptying of the bypassed regions but also to the saturation of the ones that are prioritised (Steck, 2009). Dagnogo, Ninot, and Chaléard (2012) explain that prolonged spaces crossed by the rail line between Côte d'Ivoire and Burkina Faso experience a "tunnel effect"; that is, they do not have access to transport services because some stations are not profitable for the concessionaire and therefore are closed. Contrariwise, in the case of Ghana, the century-old railways have had a long-lasting positive impact on the urban economic system, thanks to its complementarity with the posterior road network (Jedwab & Moradi, 2016). Béranger (2012), by comparing two study cases from Kenya and Mozambique, stresses the importance of balancing the import–export rail function with short-distance rail services in order to enhance development at the local level. Contrastingly, Laurance, Goosem & Laurance (2009) provide a singular favourable vision of the tunnel effect and advocates for rail lines, rather than roads, with stations in selected locations as a means to reduce the deforestation of tropical areas. If trans-African roads through large rainforest regions are inevitable, a network of conservation corridors should accompany them (Kleinschroth, 2016). In the case of the Nouakchott-Nouadhibou trans-Saharan road in Mauritania, Steck (2012) highlights that the opening of this international corridor has also had adverse effects on biodiversity in desert zones. Since classical cost–benefit analysis based on traffic forecasting cannot estimate these direct or indirect impacts, Ali et al. (2015) propose new analytical tools in order to maximise benefits (in agriculture) and to reduce negative externalities (deforestation and conflict-related impacts) of road improvements.

A number of papers published by World Bank economists reinforce the idea that the African main road network should be massively asphalted in order to catalyse trade and contribute to growth (Buys, Deichmann, & Wheeler, 2010; Calderón & Servén, 2010; Coulibaly & Fontagné, 2006). Figure 4 shows two maps developed by Buys et al. (2010), based on the Trans-African Highway Network proposed by the UN-ECA and the African Development Bank in 2003. Read out of context and uncritically by politicians and policy-makers, these maps can underpin the myth of the "structuring effects" of transport and justify decisions that are unfavourable for the sustainability of the transport system. Indeed, while the conclusions of that paper may certainly be robust, the second map seems to indicate that the upgrade of certain roads, like the ones connecting East and West Africa between the tropics, should be prioritised. However, it is reasonable to expect that the traffic on the roads with higher trade growth after upgrading may not even be close to the traffic on the roads with current higher absolute traffic, especially if the traffic of the former was nearly inexistent before construction.

The economic impact of trans-African highways and their prioritisation among other transport investments has also to be discussed in juxtaposition to the need for improving rural accessibility and opening remote areas inside a country (Mwase, 1989). Indeed, there is an undeniable pressing demand for improving rural roads in developing countries, especially in Africa where poverty prevails in rural areas (Porter, 2014) and the majority of jobs remain in the agricultural sector (Gollin & Rogerson, 2014). Also in this case, transport-led growth misperceptions and political interferences are frequent (Raballand, Macchi, & Petracco, 2010). Moreover, rhetoric in favour of transport infrastructure can be particularly harmful in certain contexts of Sub-Saharan Africa where undemocratic regimes and/or bad governance abound. Blimpo, Harding, and Wantchekon (2013), in the case of Senegal, Benin, Ghana and Mali, and Burgess, Jedwab, Miguel, Morjaria, and Padró i Miquel (2015) for Kenya, provide some startling illustrations where the political utilisation of road investments has had a negative impact by marginalising parts of the population.

The numerous works reviewed above are not exhaustive but are enough to illustrate that, in the case of Sub-Saharan Africa, efforts to translate academic research into right policies can be even more challenging than in other contexts. Growth-enhancing effects of transport infrastructure can be higher than in industrialised economies but, depending on the institutional settings, can more easily result in spatial inequality,

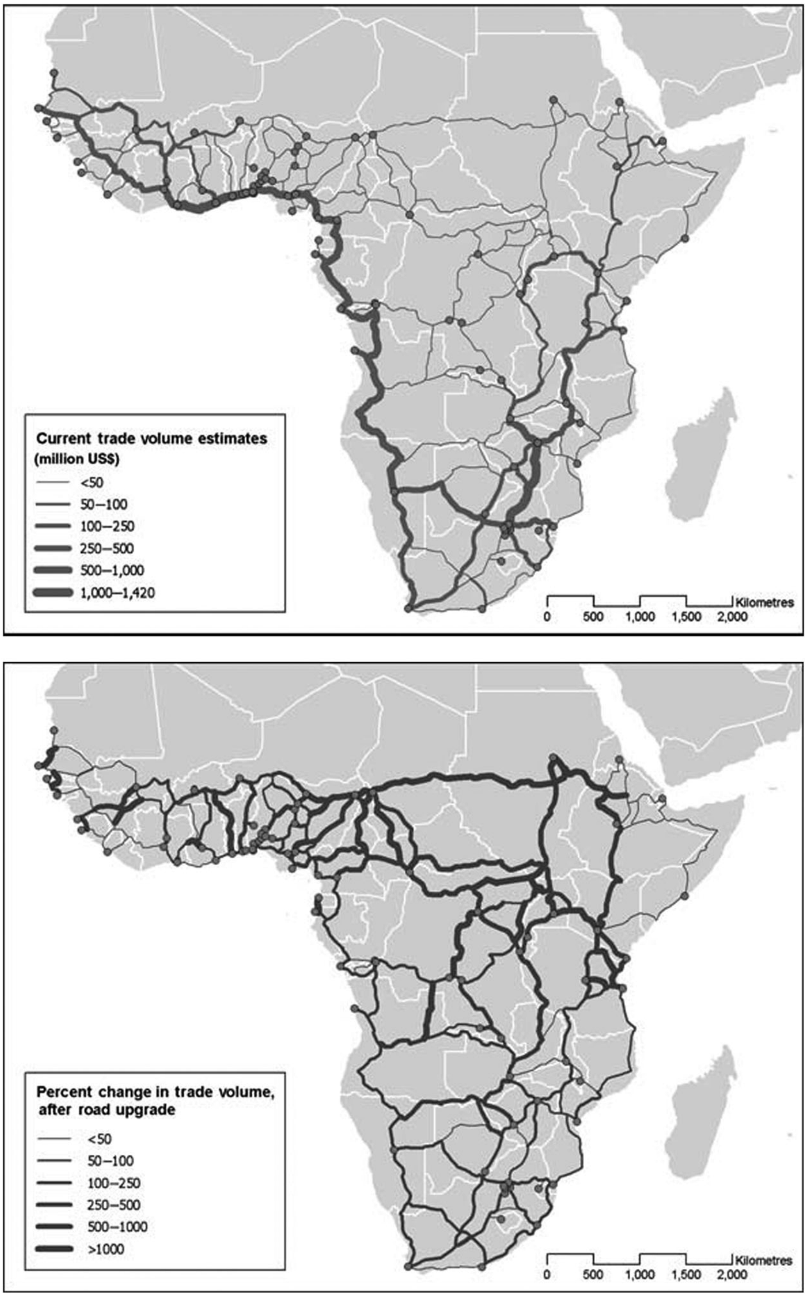

Figure 4. Trade estimates for the African road network (USD, million) and % changes in trade after road upgrading (Buys et al., 2010).

unsustainable road management costs and increased negative environmental impacts. To address these drawbacks, policies have to consider the articulation between international and local transport, in particular, the impact of the efficiency of the urban systems on the country's international competitiveness, the rural–urban dynamics (especially how agricultural production is transferred to cities) and an appropriate investment mix between corridors, the secondary network and rural roads (Godard, 1996; Raballand, Macchi & Petracco, 2010). As Lall, Schroeder, and Schmidt (2014) recommend, "policy-makers should consider spatial efficiency–equity trade-offs in deciding the spatial allocation of infrastructure investment".

4. Start filling the middle gap: secondary networks converging into cities

As shown in previous sections, a number of factors characterising network failures in the Sub-Saharan African transport system lie in the historical heritage since the colonial period. Debrie (2001) raises the question of whether African countries are skipping the fifth phase of the Taaffe et al. model, the one of the interconnection of the main inland centres, and whether these countries have directly entered in a phase of development of the "high priority main streets". However, as described in Section 2.2, the average road network expansion in Africa during the post-colonial period has been relatively low. Herbst (2000) explains that road alignments do not differ much from the ones existing in colonial times if we consider "anything that could reasonably be said to be able to carry motor traffic at least part of the year (i.e. the dry season)". Actually, even in the most remote areas, exchanges are old and have never ceased to exist (Debrie, 2001), and many of the paths taken end up becoming part of the road network. The important change lies in the service level to be considered. Many pre-existing roads have been upgraded to all-season gravel or asphalted roads since the independence. So, even if the results after the independence may have been modest in terms of network extension, service improvements have been considerable.

To better illustrate this evolution, it is useful to examine how the road networks have grown in Africa after independence. Figure 5, where spots represent cities with more than 100,000 inhabitants and red lines indicate main paved or partially improved roads, reveals that these improvements have started around main urban centres, regardless of their coastal or inland position, and that they have successively expanded until they have almost completed connectedness and improved the connectivity at the regional level. The problem, explained in Section 2.2, is that, with poor maintenance systems, service level easily deteriorates and the backlog of rehabilitation needs increases sharply.

For Hoyle and Smith (1998), historical models of transport development, including the Taaffe, Morril and Gould model for West Africa, have a global relevance and confirm that the spatial patterns of global links and urban hierarchies can be replicated in different contexts. It is in coherence with classical models advocating for the self-organising character of spatial economy and, in particular, with authors like Lösch (1954) in the sense that, in the evolution towards equilibrium between cities, there should be some predictable regularity in spatial structure. Dorosh, Wang, You, and Schmidt (2011) confirm that agricultural production and travel time to urban markets are highly correlated in Sub-Saharan Africa, which means that both population and agricultural production follow a spatial concentric distribution encircling large cities. In a similar way, Storeygard (2016) establishes that the decentralisation of economic activity is related to road service level (paved or unpaved) around cities. These findings are consistent with Jedwab and Moradi (2016) who reveal that, despite significant road

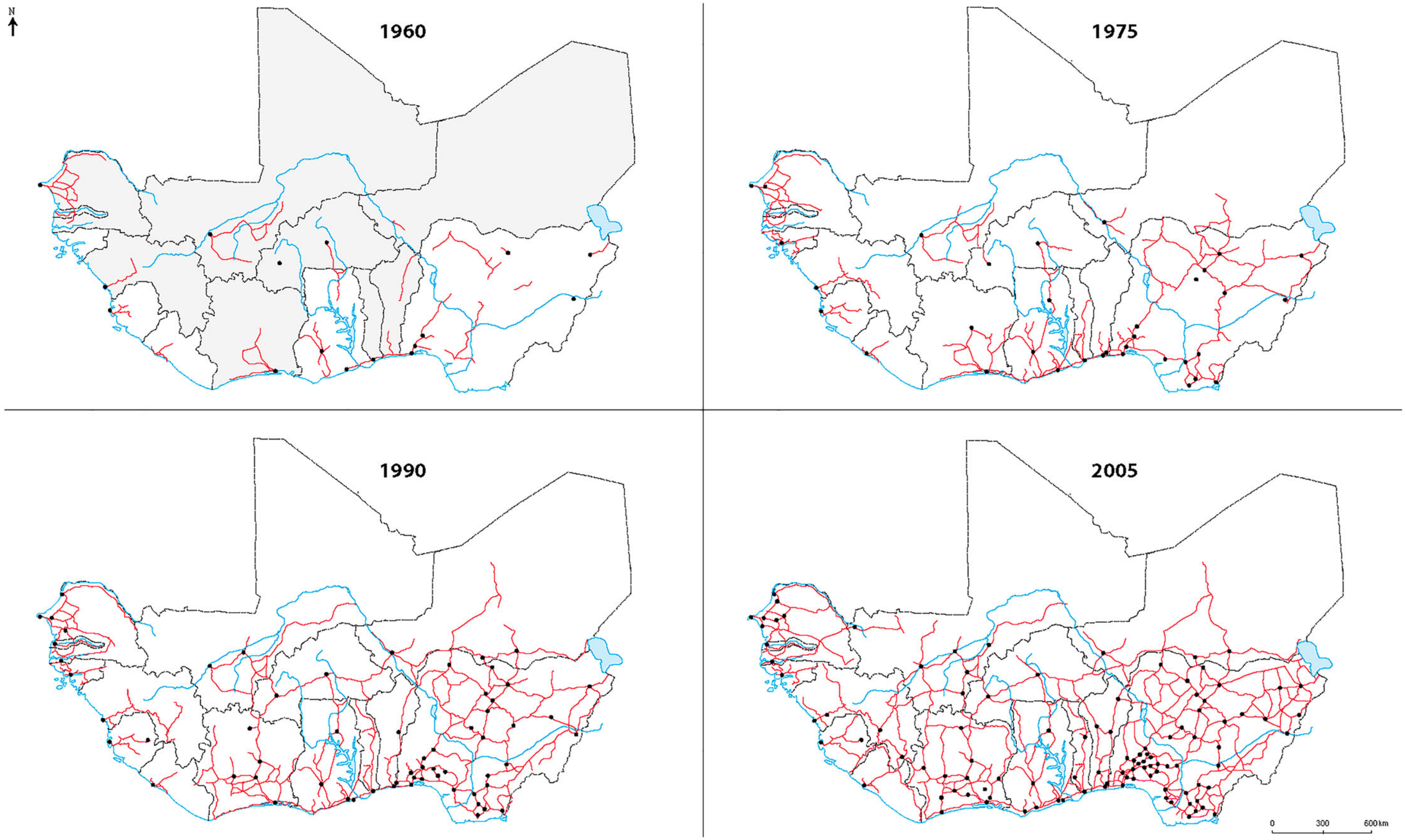

Figure 5. Main paved or partially improved roads within ECOWAS (Economic Community of West African States, 2005).

investments, urban systems have been stable in post-colonial Africa while, in line with 1933 Christaller's central place theory, complex hierarchised relations between localities have emerged. Interestingly, according to Raffestin's perspective on Christaller's theory, in the developed economies, nodes were relatively more important than networks between the industrial revolution and 1950s (Raffestin, 1987). In the same way, Taaffe et al. warn of the limits of their ideal sequence of transport development in developing countries by acknowledging that "high-priority linkages would seem to be less likely to develop along an export trunk line than along a route connecting two centres concerned in internal exchange".

Accordingly, one can say that the overall development of land transport networks in Africa has not followed significantly different patterns from the ones that occurred in other continents, as it is determined by the regional influence of the main urban centres and has been influenced by political decisions and economic activity. However, the role of nodal development is still predominant and poorly understood in the African context. For instance, recent research concludes that the urbanisation patterns in Africa are mostly driven by the extraction of natural resources rather than by an industrialisation process (Gollin, Jedwab, & Vollrath, 2016). This singularity of the growth of cities in African resource-exporting countries probably entails a relationship between them and their area of economic influence that shapes a regional development different from the one favoured by cities in industrialised contexts.

An adaptation of the Taaffe et al. model, by adding enlarged representations at the level of an interior urban centre, could be useful to better understand the critical role of African cities in the context of the local, national and international systems which they serve (Figure 6). In their model, Taaffe et al. bring forward the idea that the last phase is actually a repetition of the previous processes but at a higher level, which is in line with the hierarchical organisation of the territory anticipated by Christaller and the infrastructure-led reorganisation of urban areas. Analogously, at a lower scale, following the thesis that places cities as central drivers of urban revolutions (Soja, 2001), a process of concentration and prioritisation of linkages can be established. Thus, the initial stages of scattered ports and the introduction of inland transport modes correspond to the traditional city systems, where the role of nodes predominates and transport modes are limited. With the progressive introduction and extension of arterial and feeder railways and roads, localities expand, first around the city centre and gradually along the transport lines. The complete interconnection at the national level arrives with the generalisation of modern motorised transport modes, which in turn drastically changes the appearance of cities. However, access cannot be spatially uniform and numerous geographical areas and social groups are left segregated.

Therefore, the last and current phase of transport development should be conceived beyond the emergence of international trade corridors. Inclusiveness and integration of regional cities in the territorial networks are critical at this stage. Addressing the weaknesses of secondary transport networks encircling cities is an investment need comparable to interconnect major African capitals. In this respect, further research specifically focused on the relationship between the existing urbanisation trends and transport networks in Sub-Saharan African countries is needed and is set to become crucial in policymaking.

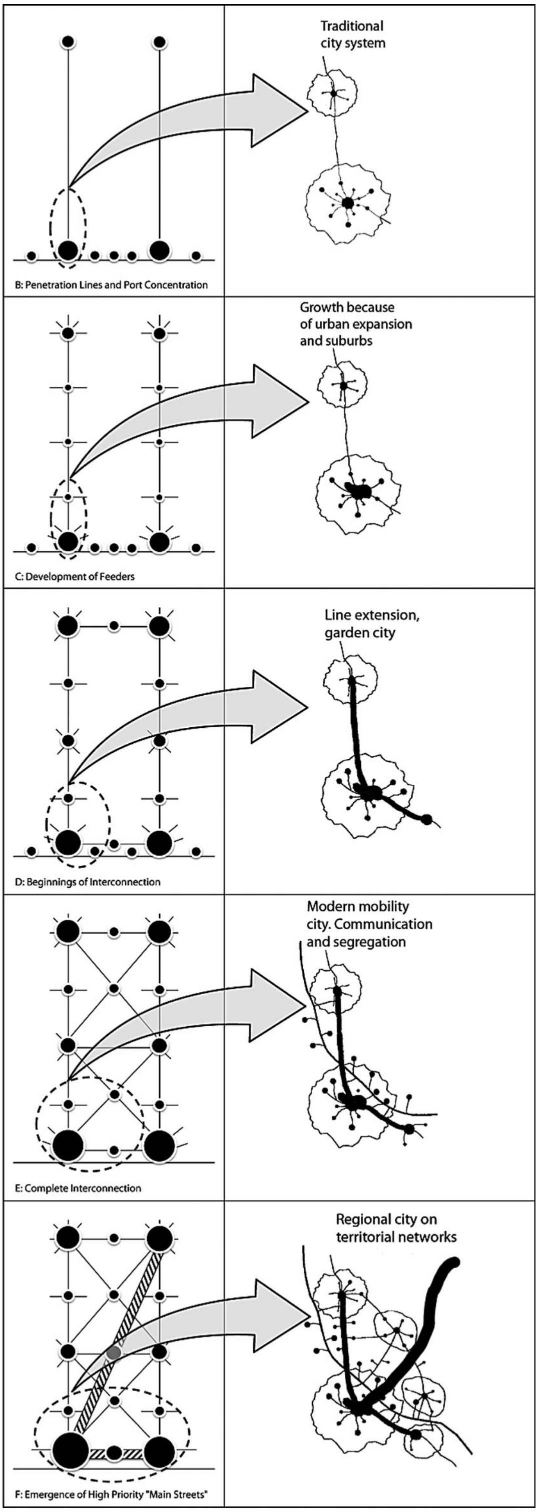

Figure 6. The correspondence between the ideal-typical sequence of Taaffe et al. (1963) and the metropolisation process model shaped by transport infrastructure (Herce & Magrinyà, 2002).

5. Conclusions

In this paper, we have reviewed the history of transport infrastructure development in Sub-Saharan Africa, in the perspective of changing development strategies that have accompanied the expansion of transport infrastructure development since the colonial rule. The mechanisms shaping this evolution show that the development of transport corridors between the main urban centres depends on the coexistence of a regional influence of these cities with specific political and economic paradigms. Past events at the continental and regional levels reveal that the continent has recently experienced different periods of infrastructure expansion that could lead again to a stagnation phase. Current transport infrastructure policies are markedly focused on the development of international rather than local connectivity. While completing most international corridors certainly needs to be considered, a balance with strategic investments at subnational and local levels in the form of secondary metropolitan roads should be encouraged. Overall, the selection and design of transport projects should be accompanied by rigorous analysis of the operating and maintenance costs and future recovery mechanisms, especially in terms of debt sustainability. These principles are widely accepted by traditional aid actors. However, their capacity to shape national or regional transport policies is becoming more and more limited. While infrastructure policies have been strongly influenced by the path dependence that originates in colonial times, nowadays, only about three quarters of the infrastructure funding comes from other than international financial institutions and bilateral aid. Moreover, multilateral banks and bilateral donors are committed to act upon the demand of developing countries, while exposed to competition among each other and the new development banks set up by emerging economies, notably China. Therefore, the future of land transport infrastructure in Sub-Saharan Africa will be determined by the influence of a greater number of international actors with different interests and political and economic leverage. The result will depend on the capacity of African governments to allocate resources efficiently, by developing appropriate public investment decision-making tools and by negotiating fair and timely agreements with foreign partners. Rather than giving preference to international corridors, transport policies aiming at further improvements of the road network should be supportive to the actual expansion patterns: developing around metropolitan areas and contributing to consolidate and amplify the already existing exchanges.

Notes

1. Plans to develop trans-African corridors are not a PIDA novelty. See, for instance, Comité de l'Alliance Internationale de Tourisme (1947) and UN-ECA and African Development Bank (2003).
2. "Second-nature geography concerns features that depend on the spatial interaction between people in an area but are not necessarily inherited", and "third-nature geography concerns features of an area that are based on prior human intervention".
3. This advance of Islam was limited to the south by the presence of the Tsetse fly (Bairoch, 1985).
4. This new development financial institution was created to complement the mission of the International Bank for Reconstruction and Development (IBRD), the first of the World Bank institutions established in 1944, which mainly offers non-concessional loans to middle-income developing countries. Instead, IDA provides grants or loans at highly concessional terms mainly to low-income countries.

5. The principle tenet is that road users should pay a fee separate from the government's taxation, a fee that is usually paid through a levy included in the fuel price and transferred by petrol companies directly to the RMFs.
6. For instance, Sitglitz was senior Vice-President and Chief Economist at the World Bank from 1997 to 2000, Venables was the Chief Economist at the UK Department for International Development (DFID) from 2005 to 2008 and Collier was the Director of the Development Research Group of the World Bank from 1998 to 2003.
7. It is worthy of mention: Foster and Briceño-Garmendia (2010), Infrastructure Consortium for Africa (2014) and World Economic Forum (2013).

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ORCID

Sergio Oliete Josa http://orcid.org/0000-0003-2337-4382
Francesc Magrinyà http://orcid.org/0000-0002-4638-0868

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Cost-effectiveness of enforcing axle-load regulations: The Douala-N'Djamena corridor in Sub-Saharan Africa☆,☆☆

Antonio José Torres Martínez[a], Sergio Oliete Josa[a,*], Francesc Magrinyà[b], Jean-Marc Gauthier[c]

[a] Directorate General for International Cooperation and Development, European Commission, Rue de la Loi 41, B-1049 Brussels, Belgium
[b] Departament d'Enginyeria Civil i Ambiental, Universitat Politècnica de Catalunya, C. Jordi Girona, 1-3, 08034 Barcelona, Spain
[c] Direction générale des infrastructures, des transports et de la mer, Ministère de la Transition écologique et solidaire, Tour Séquoia, 1, place Carpeaux, 92055 Paris La Défense Cedex, France

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ABSTRACT

Road conditions in Sub-Saharan Africa are typically poor, and only a subset of the newly constructed or rehabilitated roads reach their design life. Truck overloading generally causes this rapid deterioration. In Africa, there are few success stories on the imposition of axle-load limits. This study examines the existing regulations on the Douala-N'Djamena international road, which is the main transport corridor in Central Africa and the backbone for internal transport in Cameroon. It benefits from the detailed existing weighing data recorded since 1998 in the corridor's 10 weighing stations. This vast amount of traffic data, together with available information on road structure and deterioration over time, has been used to conduct an accurate calculation of load equivalency factors. The HDM 4 model has been applied to three scenarios between 2000 and 2015: (1) no axle-load control, (2) the real situation and (3) no overloading tolerance. Results show that axle-load regulations have been reasonably well applied in Cameroon and have contributed to maintaining the corridor in fair condition. In spite of the fact that significant traffic increases are presently counterbalancing the damage avoided by axle-load limits, benefits provided by axle-load control have been substantial: in the period of 2000–2015, every € invested or spent on axle-load control has generated more than €20 of savings in road user costs and in road maintenance and rehabilitation expenditure, which represents, in absolute terms, more than €500 million.

1. Introduction: the persistent problem of truck overloading in Sub-Saharan Africa

In the 1980s, international financial institutions started to raise the alarm regarding the rapid road deterioration in many developing countries, especially in Sub-Saharan Africa. In 1988, the World Bank published a detailed policy study on the causes and scope of this problem and on the possible options to overcome it (Harral and Faiz, 1988). The significant expansion of the road

☆ The results of this paper are presented in euros (€) for accuracy reasons. For the total period covered by the study, the Central African currency, the CFA franc, has had a fixed exchange rate to the € (1 € = 655.957 CFA francs), and most of the road investments analysed were funded in €. In addition, many of the costs considered were in € because the European Union has remained the main supplier of Cameroon. The average annual €/US$ exchange rates used in this paper can be found in Appendix C.

☆☆ The findings, interpretations and conclusions expressed in this paper are entirely those of the authors. They do not engage or represent the views of the European Commission.

* Corresponding author.
E-mail address: sergio.oliete-josa@ec.europa.eu (S. Oliete Josa).

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network during the previous two decades had not been accompanied with consistent budgets for road maintenance, and traffic had been much heavier than projected. However, sufficient evidence had already been provided to assume that overloading was the main cause of road deterioration and that neglecting road maintenance had contributed to the poor condition of the network (Lea and Ass., 1969). Moreover, it was already known that overloaded heavy vehicles threatened road safety (especially if trucks are in poor condition) and led to increased vehicle operating costs (higher fuel consumption and premature breakdown) (Keita, 1989). Above all, the 1988 World Bank study concluded, the main reason for road deterioration was institutional failure.

The implementation of axle-load control was an integral part of the reforms promoted by donors in the 1990s. By then, they already warned that axle-weight regulations were “the most important, but the most difficult to enforce” (Heggie, 1995). As a matter of fact, road maintenance policies in Sub-Saharan Africa had been quite timid with regard to pavement protection, and international development agencies did not succeed in making African countries respect the axle-load limitations already approved by most of them (Torres, 2001). Almost 20 years later, African regional economic communities still admitted that vehicle overloading was “one of the greatest threats to the sustainability of road infrastructure improvements in Sub-Saharan Africa” (SSATP, 2007). In an independent evaluation of its assistance to the transport sector, the World Bank highlighted that the lack of capacity to enforce vehicle overloading axle-load regulations was widespread in Africa (World Bank, 2007).

Since 2000, various programmes supported by the Official Development Aid (ODA) have focussed on reducing overloading and promoting axle-weight control activities with the primary objective of protecting existing road infrastructure. The evaluation of these programmes financed in Africa by the European Commission highlighted that control of overloaded vehicles has improved but continues to be inadequate due to a lack of political commitment (European Commission, 2016a). Regulations are not enforced, and weighing stations do not operate properly. Overloading continues to be a dominant and seriously damaging setback for the sustainability of the road network in many countries. According to a special report from the European Court of Auditors, most of the African countries audited failed to demonstrate sufficient commitment in implementing effective measures to reduce the incidence of vehicle overloading (European Court of Auditors, 2012). The Court noted that regional and national legislation on axle loads is not enforced effectively and that too little attention is given to the fundamental causes of vehicle overloading. The “offloading” policy of taking excess load out of a vehicle is not applied, and fines imposed are too low to have a deterrent effect. In addition, the licences of hauliers that have repeatedly infringed overloading regulations are rarely withdrawn.

The reasons behind the inadequate implementation of effective axle-load control can be characterized into two categories. The first group relates to the lack of will of many African states to tackle the overloading problem, which is closely linked to the inefficiency and corruption of the public administration responsible for road freight traffic control. Security forces and weighing agents are often bribed to overlook non-compliant loads, which occurs in the context of very low salaries in the public sector (Pinard, 2010). The second group regards the transport freight operators. Where high transport prices prevail due to overregulated transport services markets, overloading is a strategy to maximize loads and revenues from limited trips and low vehicle utilization while keeping capital costs low (purchasing second-hand trucks) and minimizing vehicle maintenance costs. Because the marginal cost of overloading is low, this practice makes sense. In addition, most stakeholders have a vested interest in operating with overloads, such as drivers, who are paid cash for extra tons loaded but not declared; intermediaries, who receive a commission based on the real truck load; and shippers, who pay lower tariff duties. Transport freight companies are poorly organized and managed and are not in a position to break the vicious cycle of transport prices and costs in which overloading is a valuable mitigation strategy (Teravaninthorn and Raballand, 2009).

Globally, few academic studies on the economic benefits of enforcing axle-load regulations exist (Moreno-Quintero et al., 2013). In Sub-Saharan Africa, research in this domain is hindered by the lack of reliable data on overloading practices (Pinard, 2010; UEMOA, 2015). The Douala-N’Djamena corridor constitutes an exception as a result of the close monitoring of overloading practices that has been carried out in parallel to new investments in load control systems. Unlike the corridors in West Africa, most of the Douala-N’Djamena corridor runs in a single country, and there are virtually no alternative routes. Thus, Cameroonian authorities have had easier conditions to enforce and keep track of load regulations (Arvis, 2011).

The lack of progress by African countries in the fight against overloading is one of the reasons why ODA’s donors are reducing road investments in the form of grants. In this manner, the 11th European Development Fund, the main aid instrument providing grants to the transport sector in African, Caribbean and Pacific countries, has seen the allocation to roads drastically reduced (Herrero et al., 2015). In a global context of economic uncertainties and financial constraints, it is of paramount importance to increase the effectiveness of ODA for the transport sector (Runji, 2015). In the next few years, aid will favour African partner countries that implement appropriate sector policies to achieve sustainable road transport with relevant and credible measures for addressing vehicle overloading (European Court of Auditors, 2012; African Development Bank, 2014). At the same time, there will be a strengthening of conditions attached to projects and programmes in relation to road maintenance and protection.

The purpose of this paper is to provide a methodology to assess the economic benefits of enforcing axle-load regulations by applying it to the specific case of the Douala-N’Djamena corridor in Cameroon. After this scene-setting introduction, the paper is structured as follows: Section 2 briefly describes the weighing control system in Cameroon. Section 3 starts reviewing the origins and fundamentals of the Highway Development and Management (HDM) model and the load equivalency concept on which this study is based. It is followed by a summary of the hypothesis and data used, the research methodology proposed and a calibration of the model. Section 4 shows the results of the application of this methodology to the Douala-N’Djamena Corridor. Section 5 presents the conclusions of this paper.

2. Axle-load control in Cameroon: A gradual but determined implementation

2.1. The enforcement of the load control system in Cameroon: origins, vicissitudes and specific regulations

As in the rest of Sub-Saharan Africa, truck overloading in Cameroon is not a recent problem. Already in 1959, at the end of the colonial period, the Road Code introduced regulations on vehicle weight and dimensions that allowed single-axle load and gross vehicle weight up to a maximum of 13 and 35 tons, respectively. However, authorities had difficulties enforcing these regulations and, in the early 1970s, requested support from international donors to finance weighing stations and technical assistance (World Bank, 2007). In 1978, the maximum single-axle load of newly imported trucks was reduced to 10 tons. For more than a decade, actions to strictly enforce these regulations remained very inefficient. The Government barely managed to construct new weighing stations and thus extend their coverage.

In 1996, the National Assembly of Cameroon approved the first legislation on road protection and road maintenance.[1] This new law introduced two fundamental principles: the creation of a Road Fund (intended to raise additional resources for road maintenance) and the enforcement of truck weight limitations (per-axle load and gross vehicle weight).

Truck weight regulations enacted in Cameroon are more permissive than those implemented in other African and European countries. In many of them, the limit for a single-axle load is 10 tons and that for gross vehicle weight is 40 tons, whereas in Cameroon they are 13 tons[2] and 50 tons, respectively. A tolerance of one ton is allowed. These apparently generous restrictions raised scepticism from many observers, and they did not prevent the existence of strong opposition from many industries relying on road transport (timber, fuel, etc.).

The current significant coverage of axle-load control in Cameroon should be understood as a result of the convergence of the political will and interests of social actors and the private sector. A common view is that the conditions of the official development aid catalysed axle-load control. According to Gauthier (in press), the long-term donor support of road protection policies has been crucial to legislation enforcement. The European Union has provided continuous institutional support since the early 1990s, accompanied by grants for road construction on the condition of progress regarding weight control. As a matter of fact, in 2012, the European Court of Auditors welcomed the appropriateness of these aid policies (ECA, 2012).

Once the 1996 law entered into enforcement, Cameroon started load control by means of weighbridges, a measure that failed because of its technical limitations and inability to calculate axle load. After this unsuccessful trial, the Government requested support from donors to introduce mobile dynamic axle weighing systems, better adapted to comply with the law. In 1998, the Ministry of Transports and Public Works conducted a baseline study to improve knowledge of traffic's impact on the Yaoundé-Douala road's deterioration (*see* Section 4). The results were enlightening: 850 out of 1000 weighed trucks at the Nomayos station were overloaded, of which 325 were very strongly overloaded (an excess load between 20 and 40%) and 340 were extremely overloaded (an excess load greater than 40%).

After this study, Cameroonian authorities started to apply repressive measures at Nomayos' mobile weighing station, which produced positive and remarkable results only seven months later. Conflict also flared up with some transporters who opposed these measures in several ways (for instance, by refusing to pay the fines or stop at the station). However, the government progressively succeeded in enforcing the regulations and building new weighing stations all along the corridor. Transporters learnt how trucks have to be loaded to avoid excess weight on the axles, and many of them adapted and/or renewed their fleets. Because the vast majority of transporters respected the rules, they understood the advantages of road protection for themselves in terms of operating costs and lifespans of their vehicles.

Following the positive experience of the Nomayos station, more weighing stations were constructed on the Douala-N'Djamena corridor. The available data showed that, during the initial years of enforcement of the law, the proportion of overloaded trucks decreased significantly. Government's credibility in implementing road protection policies contributed to new donor-funded road projects on the same corridor.[3] However, a certain number of drawbacks remained and still today hamper the attainment of Cameroonian roads' service life. The most critical one is that fuel tankers are not controlled (Ministère des Travaux Publics du Cameroun, 2006a). The power of fuel suppliers to evade weight control lies in the needs of the neighbouring countries. Attempts to enforce load regulations on tankers have caused fuel shortages in Chad and the Central African Republic, and controls have had to be lifted.

2.2. Strengths and weaknesses of the Cameroonian weight control system

The network of operational weighing stations in Cameroon has increased from 2 stations in 1998 to 17 in 2015. Out of the current 17 stations, 10 are located on the Douala-Yaoundé-Central African Republic-N'Djamena international corridor. The number of registered weightings drastically fluctuates depending on the road, ranging from less than 10,000 trucks a year in some peripheral stations to more than 250,000 on the Yaoundé-Douala road. In parallel, the government deploys annual campaigns of axle weight control with mobile scales.

Until 2015, all weighing stations were equipped with single fixed dynamic axle scales placed on one side of the road (trucks

[1] Loi n°96/07 du 08 avril 1996 portant protection du Patrimoine Routier National.

[2] 13 tons for a single axle, 21 tons for a tandem axle and 27 tonnes for a triple axle.

[3] In particular, the African Development Bank and the World Bank joined the EU in providing support to the road sector in Cameroon.

coming in the other direction had to turn back to be weighed and then turn around again to return to their initial heading). The average construction and equipment cost of a weighing station varies from €150,000 to €750,000 depending on the dimensions of the surrounding infrastructure (access roads, parking areas, drainages, etc.). Grants of the European Development Fund (EDF) have financed the construction of 11 stations, and the others have practically all been constructed with national resources.

Since 2001, operations and maintenance of the equipment, facilities and premises of the weighing stations have been entrusted to the private sector. The enterprises are recruited under three-year contracts awarded through national competitive bidding. As soon as they were privatized, stations offered high performances and were operational more than 90% of the days per year (Ministère des Travaux Publics du Cameroun, 2008). Currently, according to the annual weighing reports published by the Ministry of Public Works, the average availability rate of equipment is systematically over 95% and sometimes reaches 98% (Ministère des Travaux Publics du Cameroun, 2010 to 2015). Operations are supervised by the Ministry of Public Works, which deploys interdepartmental teams at each station (Roads, Finances, Transport, Gendarmerie). In total, the annual average operation and maintenance costs of one station, including the private firm contract in charge of maintenance and the salaries and bonuses of public staff, are approximately €160,000. Appendix A summarizes the capital and recurrent costs for all the weighing stations on the Douala-N'Djamena corridor between 2000 and 2015.

Any vehicle that exceeds the tolerance limits is fined 25,000 CFA francs/ton (38 €/ton) when the overload is less than five tonnes. Fines increase to 75,000 CFA francs/ton (115 €/ton) when the registered overload exceeds 10 tonnes. Overloaded vehicles remain immobilized at the weighing station until full payment of the corresponding fine and unloading of the excess weight are complete. This is accompanied by a warning letter. Additional expenses due to offloading are borne by the carrier. The issuance of two warning letters leads to the withdrawal of the Public Transport Card.[4] The CEMAC Community Code requires recidivist carriers to be exposed to the withdrawal of their transport license by the transport competency authority.

In 2014, according to the official annual report from the Ministry of Public Works, 1,848,332 trucks other than tankers were controlled in the 17 operational weighing stations. 109,479 were found overloaded, i.e., a national average rate of 5.92%. Lightly overloaded trucks, of less than five tonnes, represent the largest share of the amended vehicles, 98.57% or 107,913 vehicles. Gross vehicle weight overloading was 13.88% of the total amended vehicles, while axle-load overloading reached 86.12%. The biggest problem remains the fuel tankers: the percentage of overloaded tankers was 75%.

3. Research methodology

3.1. The HDM model and the load equivalency concept

The HDM model simulates the behaviour of roads throughout their lifecycle by considering the effect of traffic, their pavement structure, maintenance operations and the impact of the environment over time. At the same time, the model has the ability to estimate savings in road user costs and predict potential benefits of appropriate road management (lower travel times, reduction of accidents, less environmental effects, etc.). Firstly developed at the initiative of the World Bank, it has significantly evolved since its first version in 1968, thanks notably to empirical evidence collected in developing countries (Kerali et al., 2006). Its last release, HDM-4, is principally conceived as an economic decision-making tool for programming and planning road investments. The model is used by a number of road agencies in developing countries to evaluate and prioritize individual projects, multiannual work programmes and/or long-term network interventions. Furthermore, among other applications, HDM-4 developers claim it has utility in conducting research and, in particular, studying the economic benefits of axle-load control policies (Morosiuk et al., 2006).

HDM-4 performs analysis based on multiple data provided by the user. Required inputs include pavement structure, road geometry specifications, traffic levels and characteristics (types and loads), vehicle fleet unit costs, road conditions, maintenance operations, climate conditions, etc. In most African countries, only a small subset of the relevant data required as input for the HDM-4 model is available. Using average regional data is a current practice for analysts, but such data may significantly differ from the actual national values, and this heavily affects the output quality of HDM-4. Consequently, it is of paramount importance to collect high-quality data specific to the country of the analysis and to apply these data to carefully calibrate HDM-4. Moreover, certain authors have highlighted limitations of the HDM-4 model when studying the African context (Teravaninthorn and Raballand, 2009). On the one hand, actual vehicle fixed costs are reported to be higher than those estimated by HDM-4 due to underestimation of overheads, administrative costs, bribes, etc. However, a substantial part of these costs is financial and not economic, and this paper focuses exclusively on economic benefits of enforcing axle-load regulations. On the other hand, maintenance, fuel and lubricant costs are reported to be higher because HDM-4 uses data for new trucks as an input. In most African countries, transport companies usually purchase second-hand trucks at prices substantially below those of brand new ones. These prices can be estimated by means of local surveys. Regarding variable costs, HDM-4 allows calibration of detailed vehicle parameters to simulate real vehicle maintenance costs and the higher consumption of fuel and lubricants.

For the completion of this study, it is essential to run the model using an efficient estimation of traffic load conditions. To this end, the Equivalent Single Axle-Load (ESAL) concept generated in the 1950s in the United States in the context of the so-called AASHO Road Test has been adopted. Indeed, despite early criticisms, particularly with regard to the geographical specificity of the initial empirical tests (Rolt, 1981), ESAL is, more than fifty years later, the most-used pavement design method linking axle-load and road

[4] The Public Transport Card or "Blue Card" is a vehicle document obligatory in the CEMAC area. It is only required for public transport vehicles. It specifies the transport category of the license obtained by the vehicle operator and the transport lines that the vehicle is authorized to take.

deterioration worldwide (Hudson et al., 2007).

It is worth mentioning that, to calculate the load equivalency factors (LEFs), a simplified fourth-power ESAL formula is frequently used. This is the case of the annual weighing reports published by the Cameroonian Ministry of Public Works:

$$LEF = \left(\frac{P_i}{P_{ref}}\right)^{\alpha}$$

where

P_i = axle load recorded
P_{ref} = standard 80-kN single-axle load
α = power factor (generally equal to 4 for flexible pavement)

However, when implementing a comprehensive simulation model as HDM-4, to assess the impact of axle-load limits, LEFs can be estimated by applying the method established in *Appendix MM* of the *AASHTO Guide for Design of Pavement Structures* (AASHTO, 1986). The complete ESAL equation for flexible pavement is:

$$\frac{W_x}{W_{18}} = \left(\frac{L_{18} + L_{2s}}{L_x + L_{2x}}\right)^{4.79}\left(\frac{10^{G/\beta x}}{10^{G/\beta 18}}\right)(L_{2x})^{4.33}$$

where

W_x = axle application inverse of equivalency factors (where W_{18} = the number of 18,000-lb (80-kN) single-axle loads)
L_x = axle load being evaluated (kips)
L_{18} = 18 (standard axle load in kips)
L_{2x} (code for axle configurations)
= 1 (single axle)
= 2 (tandem axle)
= 3 (triple axle)
L_{2s} (code for standard axle) = 1 (single axle)

$G = Log_{10}\left(\frac{4.2 - p_t}{4.2 - 1.5}\right)$ a function of the ratio of loss in serviceability at time t to the potential loss taken at a point where $p_t = 1.5$

p_t = "terminal" serviceability index (point at which the pavement is considered to be at the end of its useful life)

$\beta = 0.4 + \left(\frac{0.081(L_x + L_{2x})^{3.23}}{(SN + 1)^{5.19} L_{2x}^{3.23}}\right)$ function that determines the relationship between serviceability and axle load applications

SN = structural number

As can be observed, the ESAL equation derived from the AASHO Road Test allows for a much more accurate calculation of LEFs as it takes into account the road structure, its deterioration and the axle type (single, tandem or tridem). Moreover, this is a more coherent approach since the structural number and road conditions are also key variables of HDM-4.

3.2. Hypothesis and data used to evaluate the impact of the axle-load control system along the Douala-N'Djamena corridor since 1998

The road from Douala to N'Djamena, passing through the east of Cameroon and also serving Bangui, is the main international corridor in Central Africa and the backbone of road transport in Cameroon. The HDM-4 model is applied to alternative scenarios to establish whether savings in road user costs and road maintenance and rehabilitation expenditure, thanks to axle-load control on the corridor, compensate the investments and operating costs of running the weighing stations, and whether further savings could have been obtained if load tolerances would not have been authorised. In April and November 1998, two baseline studies were conducted to estimate the real overloading impact on the Douala-Yaoundé section before and after applying repressive measures at Nomayos' mobile weighing station (Gauthier, 1998a,b). Complete data on axle loading per vehicle type from 2003 to 2015 are available via computerized records at Nomayos' fixed station, located in the Edéa-Yaoundé road section, and at nine other fixed weighing stations along the Douala-N'Djamena international corridor (see Fig. 1 and Appendix A). From these records, eight main vehicle types have been identified, which represent more than 99% of the surveyed traffic. Tandem and triple axles have been distinguished for all weighing records. The identified vehicles are rigid (P11: 2 single axles, P12: single-tandem, P13: single-triple) and articulated (S111, S112, S113, S122, S123).

The number of 80-kN Equivalent Single Axle Loads (ESALs) imposed on the road structure by each vehicle class has been calculated directly from weighing station records. An input to this calculation is the structural number (SN), which has been estimated following the method outlined in HDM 4 Model Version 1.3 (ISOHDM, 2001). Road structure data have been obtained from work contracts and supervision and evaluation reports on EDF-funded projects (Dorsch, 2004; Commission Européenne, 2012). The

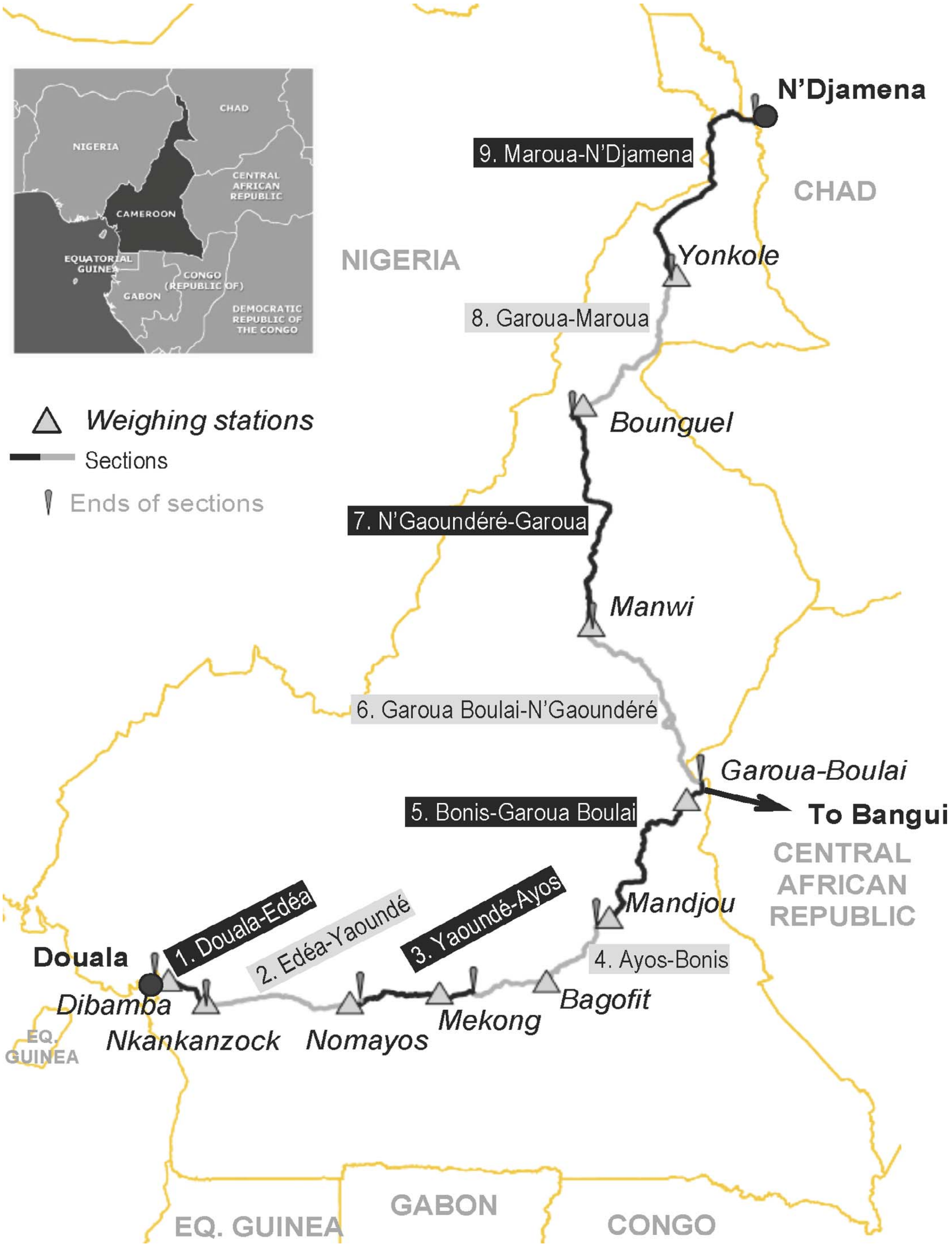

Fig. 1. The nine consolidated sections in the Douala – N'Djamena corrider used in the study.

Table 1
Average road structure of the Douala-Yaoundé section.

	Pavement	Base course	Sub-base course	Subgrade course
Type	Asphalt concrete	Bituminous	Granular: CBR ≥ 30	Granular: CBR ≥ 15
Thickness	6 cm	15 cm	30 cm	≥ 35 cm

Table 2
Consolidated sections in the Douala-N'Djamena Corridor and related road structural numbers (2000–2015).

Section	Length (km)	SN (2000)	SN (2005)	SN (2010)	SN (2015)
1.Douala-Edéa	68.90	5.3	5.1	4.6	4.2
2.Edéa-Yaoundé	176.05	5.3	5.1	4.7	4.3
3.Yaoundé-Ayos	137.26	3.6	3.2	3.9	3.8
4.Ayos-Bonis	191.55	Unpaved	Unpaved	Unpaved	3.7
5.Bonis-Garoua Boulaï	253.46	3.6	3.6	3.5	3.0
6.Garoua Boulaï-Ngaoundéré	277.50	Unpaved	Unpaved	Unpaved	4.8
7.Ngaoundéré-Garoua	272.80	3.2	3.0	2.9	2.9
8.Garoua-Maroua	204.40	3.2	3.0	2.9	3.9
9.Maroua-Chad Border	262.70	3.3	3.1	3.1	3.1

average structure for the Yaoundé-Douala road is as follows (see Table 1):

The SN remained approximately equal to 5.3 from 1998 to 2003, taking into account periodic road maintenance works that took place after road construction in 1980–85 (asphalt concrete overlays of 2.5 cm). After 2003, the SN decreased due to road deterioration, reaching approximately 4.3 in 2015 (see Table 2). Terminal Serviceability is estimated at 2.0.

The Ministry of Public Works has defined 30 road sections on the Douala-Yaoundé-N'Djamena international corridor. Traffic counts have been performed in these sections from 2000 to 2014 per vehicle type (see Appendix B). For the purpose of this study, traffic counts in the two sections adjacent to Yaoundé (Yaoundé-Nomayos: 19.7 km, and Yaoundé-Nkolafamba: 23.8 km) have not been taken into account because of high local traffic. Vehicle operating costs in these two sections have been estimated by applying traffic count results of contiguous sections, where local circulation is not relevant compared to medium- and long-distance traffic. Traffic counts are not available or reliable in some sections for a certain number of years. In such cases, estimates have been obtained by linear interpolation or extrapolation.

ESAL estimations from the ten weighing stations have been applied to the nine consolidated sections shown in Table 2. These sections are the result of aggregating the 30 road sections defined by the Ministry of Public Works, taking into account the main criteria of homogeneity for traffic, road structures and road deterioration (Fig. 1).

Estimated road structural numbers (SN) are shown in Table 2. Upgrade and rehabilitation works that took place from 2000 to 2015 have been taken into account, as well as road deterioration modelling results by applying the HDM-4 road deterioration model (see Section 4.1).

It is assumed that effective overload control for a road section started when the weighing stations became fully operational. Therefore, axle-overload values prior to 1998 are applied to road sections before commissioning of the weighing stations in these sections. This is a pessimistic assumption due to the fact that a certain number of trucks circulating through these sections were previously controlled at the initial corridor's weighing stations, such as Nomayos, and they accordingly reduced axle overloading to all their routes to the north. However, there is no data to precisely estimate this effect.

Fig. 2 shows the research methodology. First, ESALs, LEFs and average weights are estimated per vehicle type, station and year selected for analysis. These intermediary results feed the HDM-4 road deterioration model (RDM) and road user costs model (RUC). These models are run for all the overloading control scenarios, road sections and time periods. The results obtained are vehicle operating costs, travel time costs and estimation of the periodic maintenance and rehabilitation backlog. Finally, cost-effectiveness ratios of axle-load control are estimated for the overloading control scenarios.

3.3. Calibration of the models for estimating the effects of axle overload

HDM 4 software for estimating road deterioration and road user costs has been calibrated and applied. Appendix C displays the main economic data for running the HDM 4 RUC model, which are vehicle fleet economic unit costs in Cameroon from 2000 to 2015. Appendix D shows the basic utilization parameters of vehicles and road section geometry, which have not substantially varied since 2000.

Average vehicle fleet economic costs and basic utilization parameters have been obtained from a World Bank Road User Costs Study (2006) for African countries when they are not available at the national level or when average figures are difficult to estimate (passenger time, cargo delay, labour and overhead costs, kilometres and hours driven per year and vehicle, etc.). Shadow prices for fuel and gasoline have been estimated, taking into account the annual product price structure. Ex-refinery prices, total storage, transport, stabilization and distribution costs are included. All taxes, custom duties and fees have been excluded on the basis of data from IMF country reports (International Monetary Fund, 2014 and 2016). Regarding fleets, 10 vehicle types have been analysed: medium cars, pick-ups, small buses, medium buses, and trucks (P11, P12, S112, S113, S122, and S123). P13 and S111 trucks have been embedded into the P12 and S112 categories, respectively.

In the Douala-N'Djamena corridor, the rate of empty-truck return trips has recently been estimated at 85% by a World Bank project appraisal document (2014). This average has been applied to estimate the LEFs for each vehicle type and section. Axle load distribution for empty vehicles has been estimated using average observed weights and dimensions per vehicle type. Average operating weights have been obtained from weighing station records by applying the rate of empty-truck return trips. Average loads of heavy buses have been taken into account for ESAL estimation, even though their axle-load is not controlled in Cameroon. An average

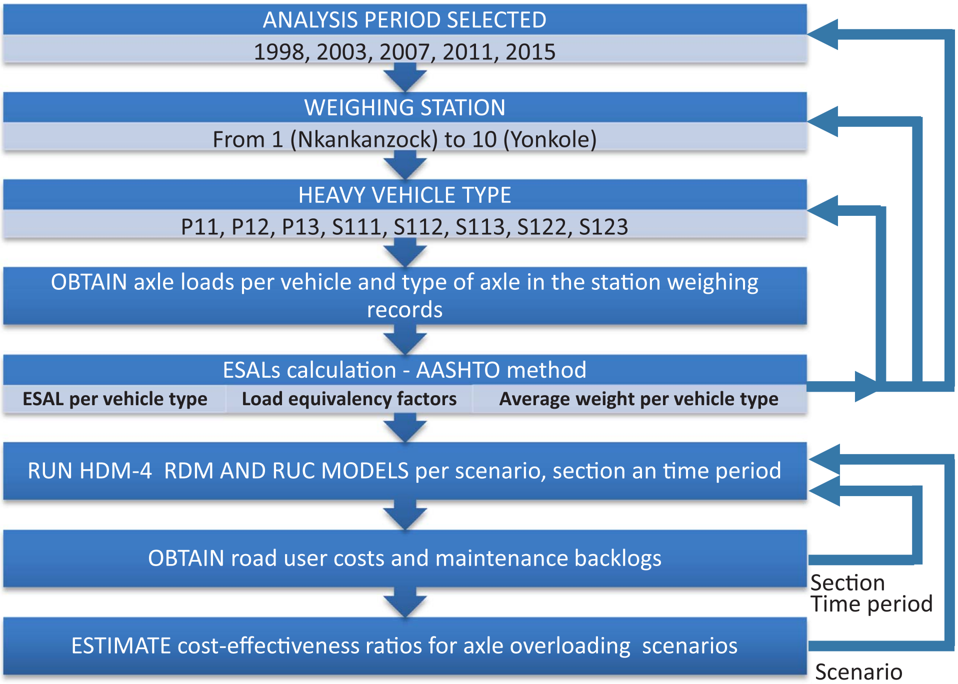

Fig. 2. Research methodology.

gross bus weight of 11.9 tonnes has been applied (4.4 tonnes for the front axle, 7.5 tonnes for the rear single axle) (World Bank, 2006).

The HDM 4 model has been applied to three alternative situations:

0. "Do nothing" scenario: the situation prevailing before April 1998 is maintained (no axle-load control). Consequently, LEFs remain the same as they were in April 1998 at the Nomayos station. It is assumed that LEFs calculated at the Nomayos station can be applied to all sections in the Douala-N'Djamena corridor. In addition, vehicle-operating weights for this scenario have been estimated from April 1998 weighing records at the Nomayos station.
1. Real situation: what has actually happened from 2000 to 2015.
2. Optimal scenario: zero overloading tolerance since 2000. This means that the 1996 legislation on road protection and road maintenance would have been strictly applied. Available data on axle loads from records at the ten weighing stations along the Douala-N'Djamena corridor have been modified to simulate strict application of axle-load legal constraints.

These three scenarios have the same maintenance standards. Differences lie in the enforcement of axle load regulations. It is assumed that traffic recorded at traffic counts from 2000 ("normal traffic") would not have substantially decreased for scenario 0 or increased for scenario 2. This assumption is highly reliable because vehicle operation costs are not very different from the three scenarios, and these differences cannot have triggered any substantial newly generated traffic. The same reason may be invoked to assume that traffic diversion for the three alternatives can be neglected, also taking into account that there is hardly any alternative road for traffic diversion along the corridor. Possible traffic diversion from other transport modes (railway from Ngaoundéré to Yaoundé and Douala) cannot be analysed in this paper. It may be assumed that slight differences for truck operation costs would not have diverted traffic from/to the railway in a substantially different manner for the three scenarios.

Maintenance and improvement standards have been applied to the three scenarios. Scenario 1 corresponds to real interventions in the corridor from 2000 to 2014. These interventions have been obtained from a World Bank appraisal document for a multimodal transport project (2014), and different European Commission (EC) project documents and evaluation reports (Commission européenne, 2005; Commission Européenne, 2012; Commission européenne, 2016b). Scenario 2 interventions would not have been different from scenario 1 ones because road deterioration would have been slightly less significant and maintenance planning would not have changed. On the contrary, scenario 0 would have required more expensive interventions to maintain the corridor at the target level of scenario 1. However, because of funding constraints, it is likely that the road condition would have worsened and that maintenance funds would not have substantially increased. Therefore, maintenance and rehabilitation backlogs increase for scenario 0 to an amount that can be estimated by the HDM 4 RDM model.

Routine and periodic maintenance, rehabilitation and upgrade costs on the corridor have been obtained from the National Road Master Plan (Ministère des Travaux Publics du Cameroun, 2006b) and several road maintenance works contracts implemented between 2004 and 2015. The routine maintenance works considered in the analysis for paved road sections is patching. Patching interventions in the corridor since 2000 were scheduled so that the maximum quantity applied to the sections needing potholing repairs was 100 m^2/km/year. Since 2000, Cameroonian road authorities have not ordered other types of routine maintenance works (crack sealing, edge repairs, etc.). The rest of the routine maintenance works (drainage works, vegetation control, road sign repairs, line marking, guard rail repair, etc.) are not included in the analysis because their estimated costs are the same for the three alternatives. Periodic maintenance works on the corridor for paved road sections were double surface dressings on a responsive basis (thickness of 2.5 cm), depending on the roughness.

Between 2000 and 2015, two sections on the corridor had been gravel roads and were paved recently: Ayos-Bonis (191.5 km, paved in 2011) and Garoua Boulaï-Ngaoundéré (277.5 km, paved in 2013). For these sections, routine maintenance works ordered by Cameroonian road authorities were periodic grading, spot regravelling and gravel resurfacing. Periodic grading took place once a year on a scheduled basis. Spot lateritic regravelling and lateritic gravel resurfacing (gravel layer thickness increased by 10 cm) were carried out on a responsive basis.

Economic unit costs have been estimated in the National Road Master Plan (2006) to 8.8 €/m^2 for patching, 6 €/m^2 for double surface dressings and 19 €/m^3 for regravelling. These costs include work control (5% for paved roads, 4% for unpaved) and exclude taxes (19.25%). Appendix E summarizes periodic maintenance, rehabilitation and upgrade works in the corridor since 2000.

Road surface condition (roughness, cracking, rut depth, ravelled area, etc.) has been assessed from inspection results taken from the 2006 National Road Master Plan and studies for new investment projects in Cameroon. Condition parameters have been determined from ratings and classification included in the manual "Road Monitoring for Maintenance Management" for developing countries (World Bank-OECD, 1990).

The time periods selected for running the HDM 4 analysis are 2000–2004, 2005–2009 and 2010–2015, aiming to accurately model road deterioration, maintenance works and vehicle attributes (especially LEFs). The initial road surface condition for 2000 is necessary to run the HDM 4 analysis for 2000–2004. It has been estimated from the 2006 National Road Master Plan and existing feasibility studies. The road surface condition obtained from running the HDM 4 RDM model has been compared to inspection results and registers of rehabilitation and maintenance projects. HDM 4 has been calibrated by adjusting maintenance and improvement standards to duly represent real road surface conditions on the corridor. Initial road surface conditions for 2005 and 2010 have been obtained from running the model for previous time periods (see Fig. 2).

4. Results

4.1. Equivalent single axle loads and load equivalency factors

ESALs are intermediary results of the methodology, which feed the HDM-4 models. ESALs have been calculated and converted into 13-ton axle loads in Table 3, which also displays LEFs per vehicle type from 1998 to 2015 at the Nomayos station. Fig. 3 shows equivalent 13-ton axle loads evolution from 1998 to 2015.

These results reveal a significant decrease of equivalent 13-ton axle loads per vehicle (from 2.87 to 1.43) associated with the short-term repressive measures applied in 1998. Furthermore, a continuous decrease was observed from 1998 to 2007 as a result of long-term axle-load control (from 1.43 to 0.69).

From 2007 to 2015, the damage to the road structure caused by the increase of overloaded trucks within the tolerance of one additional ton (13–14 tons) has increased by approximately 23%. This has added to a sharp 16.8% average annual traffic growth rate. Both factors have multiplied by 4.3 the number of annual equivalent 13-ton axle loads. This increase corresponds to a new vehicle type distribution, with a significant traffic increase of the heaviest vehicles (articulated S113, S122, S123).

The ESAL calculation procedure has subsequently been applied to the nine other fixed weighing stations along the Douala-Yaoundé-N'Djamena international corridor. The road structural numbers (SNs) shown in Table 2 have been recalculated by applying the HDM-4 road deterioration model. Final SNs calculated by HDM-4 RDM are not very different from those that have been initially estimated for ESAL calculation. To verify the stability of the results, the sensitivity of the LEFs to SN variation has been checked. An

Table 3
Annual estimated equivalent 13-ton axle loads and load equivalency factors per vehicle type. Edéa-Yaoundé road section.

Vehicle type	Apr-98	Nov-98	2003	2007	2011	2015
P11	9604	12,810	8055	6126	31,485	29,258
P12	7455	3051	4023	3670	14,600	14,338
P13	0	0	468	986	108	326
S111	0	0	0	0	162	421
S112	6021	7872	2671	1698	5552	9273
S113	1894	931	5856	8456	26,138	75,323
S122	1,35,857	66,725	31,243	26,464	63,042	60,083
S123	643	694	1966	3336	18,452	28,525
Total annual estimated	161,474	92,083	54,282	50,734	159,537	217,548
Vehicles/year	56,210	64,446	61,253	73,299	167,804	255,329
Axles/year	244,394	270,256	285,062	338,747	755,647	1,183,721
LEF per axle (13 ton)	0.661	0.341	0.190	0.150	0.211	0.184
LEF per vehicle (13 ton)	2.87	1.43	0.89	0.69	0.95	0.85

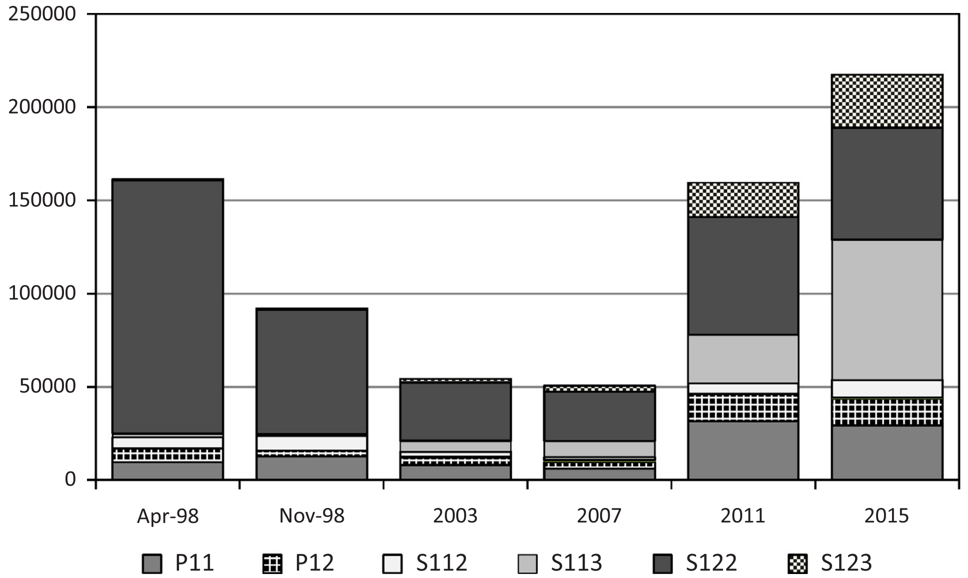

Fig. 3. Evolution of annual estimated equivalent 13-ton axle loads per vehicle type Edéa-Yaoundé road section.

SN decrease of 20% in the Edéa-Yaoundé road section (from 5.3 in 2003 to 4.3 in 2015) involves an LEF decrease per vehicle (13 tonnes) of 0.9% (from 0.852 to 0.844). The sensitivity is therefore very low, and recalculation of ESALs and LEFs is not necessary.

4.2. Economic benefits from implementing axle-load control

Results from running the HDM 4 model for the three scenarios, by section and for three time periods, are shown in Appendices F and G. Appendix F shows total road user economic costs per section and alternatives. Appendix G displays figures showing the estimated International Roughness Index (IRI) per alternative and section. IRI has been selected amongst the seven deterioration parameters that are provided by HDM 4 RDM. The Ministry of Public Works assessed the IRI on the corridor in 2016. The average results per section fit with Appendix G. Differences are observed by sub-section, which is normal when taking into account the sub-section lengths. For example, in Bonis-Garoua Boulaï (253.46 km), HDM 4 RDM estimates that the IRI = 5.4 for scenario 1 at the end of 2016. The 2016 road inspection reveals that the IRI is approximately equal to 5 for 80% of the length, but for 20%, there are potholes that have not been patched, and the IRI is estimated to be between 7 and 8. Thus, the average IRI is close to the model results.

Benefits from implementing axle-load control are twofold: reduction of road user costs (vehicle operating costs and travel time costs) and reduction of periodic maintenance and rehabilitation backlogs. The first benefits have been calculated directly by the model and are extracted from the table in Appendix F. The total vehicle operation undiscounted benefits provided by axle-load control are estimated at €411.83 million for the analysis period of 2000–2015 (scenario 1). Fig. 4 shows the amount of the discounted benefits depending on the economic discount rate. Applying the equivalent inter-annual inflation rate in 2000–2015 (2.44%), the net present value of road user benefits reaches €470.42 million. For the economic discount rate traditionally used by the World Bank for transport projects in developing countries (12%), the net present value of these benefits reaches €852.29 million.

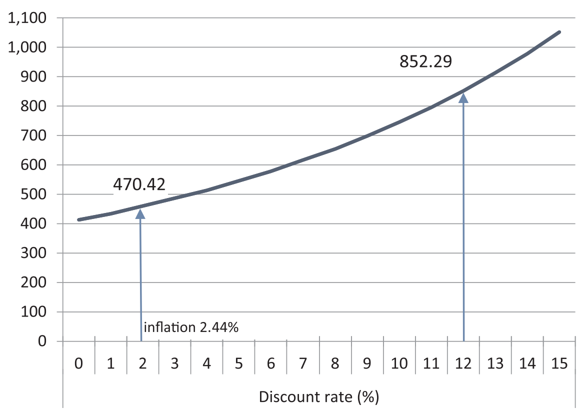

Fig. 4. Net present value of road user benefits provided by axle-load control, in millions EUR.

Table 4
Savings in periodic maintenance and rehabilitation costs in the corridor in 2000–2015 per consolidated section and scenario compared to scenario 0 (millions EUR).

Section	Scenario 1	Scenario 2
1.Douala-Edéa	16.674	16.915
2.Edéa-Yaoundé	31.865	32.394
3.Yaoundé-Ayos	7.204	7.547
4.Ayos-Bonis	4.310	4.501
5.Bonis-Garoua Boulaï	6.717	6.717
6.Garoua Boulaï-Ngaoundéré	2.081	2.220
7.Ngaoundéré-Garoua	21.278	22.915
8.Garoua-Maroua	1.022	1.022
9.Maroua-Chad Border	7.487	8.538

With regard to the reduction of maintenance backlogs, the estimation is based on the main road condition parameters obtained by the model, especially the IRI (Appendix G). Considering that a threshold for road rehabilitation of paved roads may be established in Cameroon as IRI = 12, that for new paved roads IRI = 2 and that average road service life is 20 years, it is possible to estimate the amount of this backlog maintenance in 2015 by applying average periodic maintenance and rehabilitation costs in the corridor in 2000–2015. Table 4 shows this estimation per section compared to scenario 0. The total savings in maintenance and rehabilitation backlogs provided by axle overloading control are estimated in 2015 at €98.64 million for scenario 1 and at €102.77 million for scenario 2.

The following Table 5 summarizes all the benefits that scenarios 1 and 2 provide compared to scenario 0.

4.3. Estimating cost-effectiveness ratios of axle-load control

Cost-effectiveness is a technique for comparing relative costs and effects associated with two or more courses of action. To estimate cost-effectiveness indicators for the three scenarios, investments and operating costs for axle-load control in the corridor since 2000 have been obtained. These costs have been converted into economic costs by subtracting taxes. The following Table 6 summarizes them as a function of the economic discount rate:

Cost-effectiveness is typically expressed as an incremental cost-effectiveness ratio (CER), in this case, change for output savings divided by input costs. Let NPV_{ruc} be the net present value for total road user costs, NPV_{bk} the net present value for total periodic maintenance and rehabilitation backlogs, and NPV_{alc} the net present value for investments and operational expenses in axle-load control.

The CER may be expressed separately for reduction of road user costs (CER_{ruc}) and reduction of periodic maintenance and rehabilitation backlogs (CER_{bk}) as follows:

$$CER_{ruc} = \frac{NPV_{ruc}(alt_0) - NPV_{ruc}(alt_1)}{NPV_{alc}(alt_1)} \quad CER_{bk} = \frac{NPV_{bk}(alt_0) - NPV_{bk}(alt_1)}{NPV_{alc}(alt_1)}$$

It is also possible to express both reductions in one aggregate CER indicator ($CER_t = CER_{ruc} + CER_{bk}$). The results for scenarios 1 and 2 depending on the economic discount rate are provided in the following Table 7:

These results reflect the EUR gained by the national and regional economy for every EUR invested or spent in axle-load control with related policy enforcement from 2000 to 2015.

Cost-effectiveness for scenario 2 is slightly higher than it is for scenario 1. This is because full strict enforcement of axle-load regulations would mainly involve overloads between 13 and 14 tonnes. These overloads have a reduced impact on road deterioration and, thus, vehicle operating costs. However, the savings of scenario 2 compared to those of scenario 1 (almost €10 million undiscounted for road user costs and maintenance backlog in the total 1844.6 km) are very significant if it is taken into account that they could have been reached at zero cost.

Estimation of cost-effectiveness for road user costs is much more accurate than cost-effectiveness for reducing periodic maintenance and rehabilitation backlogs. Even though this study has estimated maintenance backlogs by applying the HDM 4 road deterioration model, whose results have been verified by the 2016 road inspection, future maintenance and rehabilitation costs per section can only be estimated roughly, and the IRI is not the only criterion to decide when these works should be carried out. However, even if this estimation is inevitably rough, it is important to incorporate CER_{bk} in the results and to aggregate it to CER_{ruc}. This is because maintenance backlogs cannot be neglected compared to savings in RUC (they are approximately 20%), and they are a

Table 5
Total discounted benefits (2015) of scenarios 1 and 2 compared to scenario 0.

Reduction of maintenance and rehabilitation backlog in 2015 (millions EUR)			Reduction of road user costs (millions EUR)		Total benefit (millions EUR)	
Scenario 1	Scenario 2	Discount rate	Scenario 1	Scenario 2	Scenario 1	Scenario 2
98.64	102.77	0%	411.83	417.37	510.47	520.14
		6%	578.88	586.02	677.52	688.79
		12%	852.29	861.89	950.93	964.66

Table 6
Total discounted investments and operating costs for axle-load control in the corridor since (2000–2015).

Discount rate	Investment and operating costs for axle-load control in millions € (2000–2015)
0%	21.249
Inter-annual inflation rate (2.44%)	24.917
6%	31.696
12%	48.597

Table 7
Cost-effectiveness ratios for reduction of road user costs, reduction of periodic maintenance and rehabilitation backlogs and aggregated reduction of costs (discounted in 2000–2015).

Cost-effectiveness ratio	Discount rate	Scenario 1	Scenario 2
CER_{ruc}	0%	19.38	19.64
	6%	18.26	18.49
	12%	17.54	17.73
CER_{bk}	0%	4.64	4.84
	6%	3.11	3.24
	12%	2.03	2.11
CER_t	0%	24.02	24.48
	6%	21.37	21.73
	12%	19.57	19.85

fair indicator of the road national investments that have been saved by the enforcement of axle-load control.

As a rule of thumb, useful to convey these results to African transport sector stakeholders and decision makers, every € invested or spent in axle-load control duly enforced on a main highway corridor generates approximately €20–€25 of savings for the national and regional economy.

5. Conclusions

Vehicle overloading persists in Sub-Saharan Africa after many years of strategies and high-level political decision-making measures fighting against it. This lack of results has led many observers to consider axle overload as a very complex phenomenon from which African countries cannot escape due to many overlapping problems deeply rooted in African transport systems.

However, looking at this problem from a pragmatic view, this article shows that, even in a priori unfavourable countries in the fight against overloading, such as Cameroon, it is possible to ensure substantial savings for national and regional economies in vehicle operating costs and road maintenance and rehabilitation expenditure. In the Douala-N'Djamena international corridor, every € invested or spent in axle-load control duly enforced by the authorities in 2000–2015 has generated €19.4 savings in road user costs and €4.6 savings in road maintenance and rehabilitation expenditure.

Effective action against vehicle overloading cannot be limited to the installation and operation of weighing stations, not even with the full enforcement of axle-load regulations. It must be extended to all the sector stakeholders responsible for truck overloading, especially transport companies, shippers and logistic operators. A broad set of actions are also needed to tackle the problem at the regional level and at different subsector levels (transport liberalisation, port operation reforms and coordinated regional actions) because fighting overloading in some countries and corridors and not in the others may cause distortions in competition and traffic diversions.

In Cameroon, despite the remarkable benefits of axle-load control, the situation remains difficult. Enforcement of weigh limits is still perceived by many freight operators as harassment by the authorities. Tankers can continue to circulate overloaded, and in recent years, there has been a significant increase of heavy-vehicle traffic. Taking into consideration that load tolerances are still admitted, section 4 shows that these circumstances are progressively neutralizing the damage avoided by axle-load regulations. Moreover, the growth in road traffic has had an unattended negative effect: considerable traffic jams and rapid road deterioration around some of the more transited weighing stations. This has led to the closure in 2015 of the Dibamba station located on the Douala-Edéa highway section. Cameroonian authorities should redouble their efforts to sustain a high-quality control system by improving the existing stations (weighing in both directions, weigh-in-motion systems, etc.), building and operating the foreseen new ones, fully applying the law, and better communicating the benefits of axle-load control to freight companies, sector stakeholders and the public in general. Overall, international development institutions should strengthen their use of conditions attached to transport programmes and sector policy dialogue, defining measurable and time-bound formal requirements to address vehicle overloading. These requirements should be supported by in-depth studies and research, which will provide African decision-makers with adequate justification to substantially improve the enforcement of axle-load regulations. The methodology proposed in this paper aims at contributing to the generation of empirical evidence supporting this policy-making.

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Supplementary materials

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EU–Africa Strategic Corridors and critical raw materials: two-way approach to regional development and security of supply

Claudia Baranzelli [a,b], Gian Andrea Blengini [b], Sergio Oliete Josa [c] and Carlo Lavalle [a]

[a]Joint Research Centre, European Commission, Ispra (VA), Italy; [b]Department of Environment, Land and Infrastructure Engineering, Politecnico di Torino, Turin, Italy; [c]Directorate-General for International Partnerships, European Commission, Brussels, Belgium

ABSTRACT

The paper has two interconnected bodies. The first one deals with mineral resource indicators and their role in drawing 11 EU–Africa Strategic Corridors, in a broader context of Africa–EU partnership. The second strives to understand how such Strategic Corridors are also mineral corridors, i.e. development promotors that use mineral resources as a catalyser to create and strengthen value chains and territorial organisation, boosting economic and societal development at regional scale. The results can help understand how Strategic Corridors can improve access to the present and future mines, mitigating the risk of supply disruptions of critical raw materials for the EU.

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1. Introduction

There are no widely accepted definitions of ‘corridors’, and the concept is used in different contexts by different players, often preceded by specific qualifiers, such as ‘economic’, ‘development’, ‘strategic’, ‘resource’, etc., depending on the sectors of interest and with given objectives in mind [1]. Pottier dedicated extensive research to study the phenomenon of corridors, following their evolution from mere transport link to multi-purpose communication axis, which can facilitate the creation of agglomeration economies [2].

In the case of ‘resource corridors', the concept has been frequently reported in the literature, often in combination with other qualifiers, such as 'growth' [3] [4]. Interpretations may vary and attempts have been made to give more comprehensive definitions, such as the one proposed by the World Bank and according to which a 'resource corridor' is 'a sequence of investments and actions to leverage a large extractive industry investment in infrastructure, goods and services, into viable economic development and diversification along a specific geographic area' [5]. Other organisations and actors have adapted the same definition: in 2015, the World Wildlife Fund (WWF) and UKaid, together with the Adam Smith International (ASI), implemented the Integrated Resource Corridors Initiative (IRCI) and expanded 'viable economic development' into 'sustainable, inclusive economic development' [6] [7].

From an economic and social development perspective, ‘corridors’ are most often understood as efficient transport systems that facilitate trade, attract investment and generate economic activities along a specific territory. Besides transport infrastructures, corridors can support the deployment of digital and energy networks as well. In an evolutionary framing, these functions may also be seen as

CONTACT Claudia Baranzelli claudia.baranzelli@gmail.com Joint Research Centre, European Commission, Ispra (VA), Italy

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stages of the same development axis, evolving from a pure transport corridor to a logistics, trade, economic and, eventually, growth or development corridor [8] [9].

As the African continent is concerned, often the use of the 'corridor' term is derived from a restrictive view that, in practice, indicates road highways that links, for instance, country capitals or ports with hinterland and omits the aspects of multimodality, rural development, cities, logistics, digitalisation, etc. Planning and implementation challenges often hinder a full-fledged realisation of corridors [7], which should include both 'hard' and 'soft' infrastructure [10]. Unforeseen and occasionally adverse impacts that corridor development has on different population groups [11] [12] [13] are often neglected, together with the development of local connectivity [14].

Coming closer to EU–Africa inter-relations, large-scale investments in cross-border corridors have become a priority of governments, Regional Economic Communities (RECs) and the African Union (AU). These initiatives are, however, often sparse and not harmonised [14].

The concept of 'EU–Africa Strategic Corridor', recently developed by the European Commission [1], goes beyond the infrastructure elements and entails also the area of interest along them, i.e. the adjacent territory that is influenced by those infrastructures. From this perspective, EU–Africa Strategic Corridors are intended as a mean to support the strengthening and creation of value chains and territorial organisation, embracing both rural and urban areas. This is also the definition embraced in this paper.

In the context of the 2021–2027 EU programming exercise, the Global Gateway Africa–Europe Investment Package will support the creation of strategic, sustainable and secure transport corridors and support value chains, services and jobs that can benefit industries in both Africa and Europe [15,16]. Strategic Corridors are also meant to support territorial development (both rural and urban) through reliable networks and services, including the deployment of digital and energy-related infrastructure. In such a context, the Joint Research Centre (JRC) and the Directorate-General for International Partnerships (DG INTPA) of the European Commission have initiated in 2020 a project on 'Strategic Corridors and Urban Systems in Africa' (CUSA) [1].

The development of Strategic Corridors is meant to facilitate mobility and trade within Africa, as well as between Africa and Europe. They underpin the organisation of the whole territory, functionally linking rural and urban areas through reliable networks and services that create jobs and support value chains that can benefit industries in both Africa and Europe.

As the present paper is concerned, objectives and novelty are multi-fold. The paper starts from a summary on how the EC has set an ad-hoc methodology to identify and characterise Strategic Corridors using a wide range of indicators (more than 140), based on large volumes of data from multiple sources. The work then emphasises the role of the mining sector and mineral resource deposits in the search for indicators and underlying data. Both mineral-related indicators that were prioritised in the selection of corridors and indicators that were discarded are discussed by highlighting pros and cons.

Out of 55 corridors initially identified through an iterative step-wise delineation approach, a restricted set of 11 corridors has been determined using a combination of machine-based approach and policy-prioritisation process: therefore, a second body of research strives to investigate on how selected corridors can be functional to the development of the mining sector and in turn beneficial to the regional economy at a broader sector scale. Mineral resources were, in fact, embodied in 1 out of the 32 prioritised indicators, so not necessarily the final Strategic Corridors are also mineral resource corridors such as those discussed in the recent scientific literature [3].

As a final novel contribution, the paper interlinks the selected corridors with current and future critical (and non-critical) raw material projects, with special attention to battery materials, which in turn can be regarded as a supply risk mitigation strategy from the EU side [17]. Critical and non-critical raw materials are in fact crucial to Europe's economy, as they form a strong industrial base, producing a broad range of goods and applications used in everyday life and modern technologies. Reliable and unhindered access to raw materials, also through strategic international initiatives and partnerships, is a growing concern within the EU. To address this challenge, the European Commission strives to develop and keep up to date criticality and risk assessment metrics [18] [19].

2. Materials and methods

2.1. Identification, characterisation and ranking of EU–Africa Strategic Corridors

The Global Gateway Africa–Europe Investment Package [16] supports the creation of Strategic Corridors that can benefit industries in both Africa and Europe. The European Commission (Directorate-General Joint Research Centre [DG-JRC] and Directorate-General for International Partnerships [DG-INTPA]) has recently completed a project on 'Strategic Corridors and Urban Systems in Africa – Phase 1' (CUSA) with the aim to support decision-making towards a limited number of Strategic Corridors in Africa [1].

CUSA project was aimed at (1) facilitating intra-African and Africa–Europe trade and improving sustainable, efficient, safe and secure connectivity between the two continents, as well as (2) developing diversified value chains in Africa that can benefit both African and European industries.

At the core of CUSA, a quantitative methodology has been developed, made of three main steps: (1) delineation (or identification), (2) characterisation and (3) optimisation of corridors, followed by a last qualitative step (Figure 1).

The first phase entailed the delineation of the actual corridors of potential interest, focusing on main transport connections (road, railways and waterways) and the area of interest along them. Once the corridors had been identified, they were characterised by means of quantitative indicators that covered several topics and that could describe the performance of each corridor regarding, for instance, economy and investments, or connectivity and logistics. During the phase of optimisation, the corridors were compared and ranked according to the priorities set by four different scenarios, all aligned with Africa–EU policy strategies and each with a different focus:

- Strengthening Europe-Africa connectivity;
- Sustainable growth and jobs;

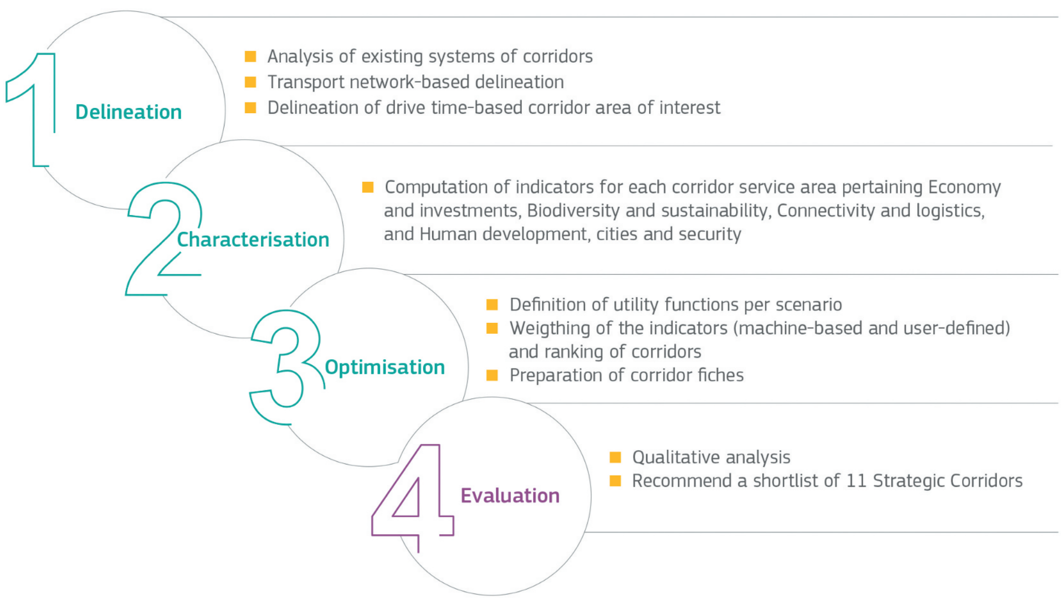

Figure 1. Overview of the methodology applied in the CUSA project – Phase 1 [1].

- Green deal;
- Human development, peace and security.

The evaluation had to address:

- Economy and investments;
- Connectivity and logistics;
- Biodiversity and sustainability;
- Human development; and
- Cities and security.

In order to cover such a wide range of topics, an extensive research was carried out to identify the best data sources, in terms of reliability, comprehensiveness, completeness, geographical coverage, geographical detail and homogeneous quality [1].

Out of 141 indicators, 32 were finally selected and used as input to the multicriteria analysis. Its scope was to order all 55 corridors according to their overall performance over the selected indicators. This exercise was repeated four times, once per scenario, on the basis of four different sets of utility functions and weights. Each utility (or 'objective') function indicates whether the objective, measured by the associated indicator, is to minimise or maximise it, i.e. lower or higher values of the indicator are more desirable. Each utility function was linked to a weight that translates the relative importance of the associated criterion with respect to all other criteria. The human development and peace and security, green deal and sustainable growth and jobs scenarios received machine-based weights, whereas for the Strengthening Europe-Africa connectivity scenario user-defined weights were applied. The use of machine-based weights guaranteed the transparency of the process while keeping it relatively simple. In the case of the EU scenario, the adoption of user-based weights allowed to directly control the importance of a few key criteria and indicators, also discussed with the involved stakeholders.

Eventually, the utility functions and weights were employed to produce the four rankings. Two ranking methods were applied – SAW (Simple Additive Weighting) and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution). These are among the most widely used multi-attribute decision techniques: the literature generally considers TOPSIS method more accurate than SAW method in calculating distances from the extreme (best or worst) options (Chen, [20] 2012). Results from both TOPSIS and SAW were then compared in order to ensure their reliability, guaranteed if both methods had generated similar outcomes. In that case, the final rankings were derived from the results generated by TOPSIS. Final scores range from 0 (worst performance) to 1 (best performance): a higher rank value indicates that, overall, the specific corridor better fits the criteria represented by the objective function.

This method allows to identify relative differences in the performance of corridors across the four scenarios, as each corridor may score similarly or substantially different across them.

The most promising corridors were identified based on the Kendall coefficient [21], which is a similarity measure and led to the selection of the top 20 positions across the four scenarios.

The resulting list is composed by 31 Strategic Corridors, with the following geographical distribution:

- 5 corridors are located in the Northern region (Tangier-Tunis, Dakar-Tangier, Tunis-Cairo, Cairo-Khartoum and Algiers-Kano-Niamey);
- 9 corridors run across predominantly the West region (Abidjan-Lagos, Abidjan-Ouagadougou, Lagos-Niamey-Kano-Port Harcourt, Dakar-Abidjan, Bamako-N'Djamena, Cotonou-Niamey, Dakar-Banjul-Bamako, Lomé-Ouagadougou and Accra-Ouagadougou);
- 3 corridors are mainly located in the Central region (Lagos-Kinshasa, Douala-N'Djamena and Douala-Kampala);

- 6 corridors run mainly across the East region (Kismayo-Addis Ababa, Lamu-Mtwara, Mombasa-Dar es Salaam-Addis Ababa, Asmara-Addis Ababa, Beira-Lubumbashi and Mombasa-Kisangani); and
- 8 corridors are predominantly located in the Southern region (Maputo-Gaborone, Durban-Lusaka, Luderitz-Johannesburg-Durban, Johannesburg-Mbeya, Luanda-Mbuji Mayi, Walvis Bay-Kinshasa, Cape Town-Windhoek and Walvis Bay-Gaborone).

The above corridors were eventually provided in input to the decision-making process in charge of identifying a preliminary set of Strategic Corridors as best candidates to be supported under the programming framework of the NDICI-Global Europe [22]. Qualitative and policy-related considerations contributed to the shortlisting of 11 corridors: amongst other factors, the process took into account the distinction between corridors mainly located in Northern Africa and sub-Saharan Africa; the geographical balance amongst African regions; and the possibility to leverage long-standing work on infrastructures, developed by partnerships between European and African public institutions and private sector. The short-listed corridors were formalised in the conclusions of the sixth European Union–African Union Summit and were presented to public and private investors, e.g. at the 7th EU–Africa Business Forum (https://www.euafrica-businessforum.com/en).

2.2. Availability, selection and weighting of mineral-related indicators

All the indicators have been selected to be highly relevant to the specific criteria and, at the same time, applicable to all corridors.

The proposed indicators with a direct connection to mineral resources were originally seven (Table 1), six of which from S&P Global Market Intelligence [23] and one from the International Council on Mining and Metals [24].

Several more indicators that are indirectly correlated to the mining sectors were identified, among which:

- Number of ports
- Railways
- Main roads
- Electricity from renewable sources
- Protected areas
- Conflict areas

The seven mineral resource indicators were found to be similar and highly correlated to each other when screened against the adopted criteria:

- Avoid collinearity as much as possible, inspecting correlation plots between pairs of indicators and computing the Generalised Variance Inflation Factor (GVIF);
- Avoid indicators characterised by the presence of outliers and the rest of the values distributed with very low variability;
- Between two similar indicators, i.e. indicators measuring the same phenomenon, the preference was given to the one with the simpler definition and easier explanation for non-experts;
- Between two highly correlated indicators, but measuring different phenomena, the preference is given to the one with the higher policy relevance;
- Between two indicators measuring the same phenomenon, but the first one referring to historical data, while the second one referring to projections, the preference was given to the projections.

Table 1. Mineral resource-related indicators initially identified in CUSA project (source [1].

Indicator	Description	Units	Highest geographical detail	Source
Mineral resource availability (in number)	Expressed as number of mining sites (properties). All mining sites are considered, with the exception of those that are currently closed and classified as inactive.	[#]	Mining site location	S&P Global
Mineral resource availability	Expressed in mass (tonnes). All mining sites are considered, with the exception of those that are currently closed and classified as inactive. Of these mining sites, only those with reported reserve/resource estimates are considered.	[t]	Mining site location	S&P Global
Mineral resource value	Expressed in *in-situ* value ($). All mining sites are considered, with the exception of those that are currently closed and classified as inactive. Of these mining sites, only those with reported reserve/resource estimates are considered.	[10^6 $]	Mining site location	S&P Global
Mineral resource at risk (in number)	Share of mining sites for which at least two categories of risk among political, operational, security and terrorism, are classified as either 'extreme' or 'high'. All mining sites are considered, with the exception of those that are currently closed and classified as inactive. Of these mining sites, only those with reported reserve/resource estimates are considered. The percentage is computed on the number of mining sites.	[%]	Mining site location	S&P Global
Mineral resource at risk (in availability)	Share of mineral resources for which at least two categories of risk among political, operational, security and terrorism are classified as either 'extreme' or 'high'. All mining sites are considered, with the exception of those that are currently closed and classified as inactive. Of these mining sites, only those with reported reserve/resource estimates are considered. The percentage is computed on the availability (tonnes) of the resources.	[%]	Mining site location	S&P Global
Mineral resource at risk (in value)	Share of mineral resources for which at least two categories of risk among political, operational, security and terrorism are classified as either 'extreme' or 'high'. All mining sites are considered, with the exception of those that are currently closed and classified as inactive. Of these mining sites, only those with reported reserve/resource estimates are considered. The percentage is computed on the *in-situ* value ($) of the resources.	[%]	Mining site location	S&P Global
Mining contribution index (MCI)	Average value of the MCI of countries in the corridor. MCI is a composite index comprising four indicators, each capturing different aspects of mining's contribution to national economies: • Mineral and metal export contribution. • Increase/decrease in mineral and metal export contribution. • Mineral production value as a percentage of GDP. • Mineral rents as a percentage of GDP.	[-]	Country, redistributed proportionally to the *in situ* value of the mining sites located within the corridor area	ICMM (International Council on Mining & Metals)

Table 2. Distribution of mining properties across the Strategic Corridors.

Strategic Corridor	Mining properties (number)
Abidjan-Ouagadougou	138
Cotonou-Niamey	15
Praia-Dakar-Abidjan	282
Abidjan-Lagos	130
Mombasa-Kisangani	87
Douala/Kribi-Kampala	45
Cairo-Khartoum-Juba-Kampala	37
Libreville/Kribi-N'Djamena	36
Dar es Salaam/Mombasa-Addis Ababa-Berbera/Djibouti	65
Durban-Lusaka	596
Maputo-Gaborone-Walvis Bay	602

A mining property can be associated with more than one corridor in case it is located in an area of overlap between two or more corridors.

As a consequence, only one indicator based on S&P Global data was retained. Such an indicator, named as 'Mineral resources', is expressed as number of mining properties, i.e. all mining sites, with the exception of those that are currently closed and classified inactive. Moreover, MCI was found to be only partially useful, as it is referred to the country as a whole and it does not allow to distinguish different regions or territories of the same country.

For what concerns indicators directly (mineral resources) and indirectly connected to mineral resources (port distinct connections, average drive time to the nearest sea port, protected areas, renewable resources, high- and medium-voltage infrastructure and conflict-prone areas), different weighting sets have been adopted.

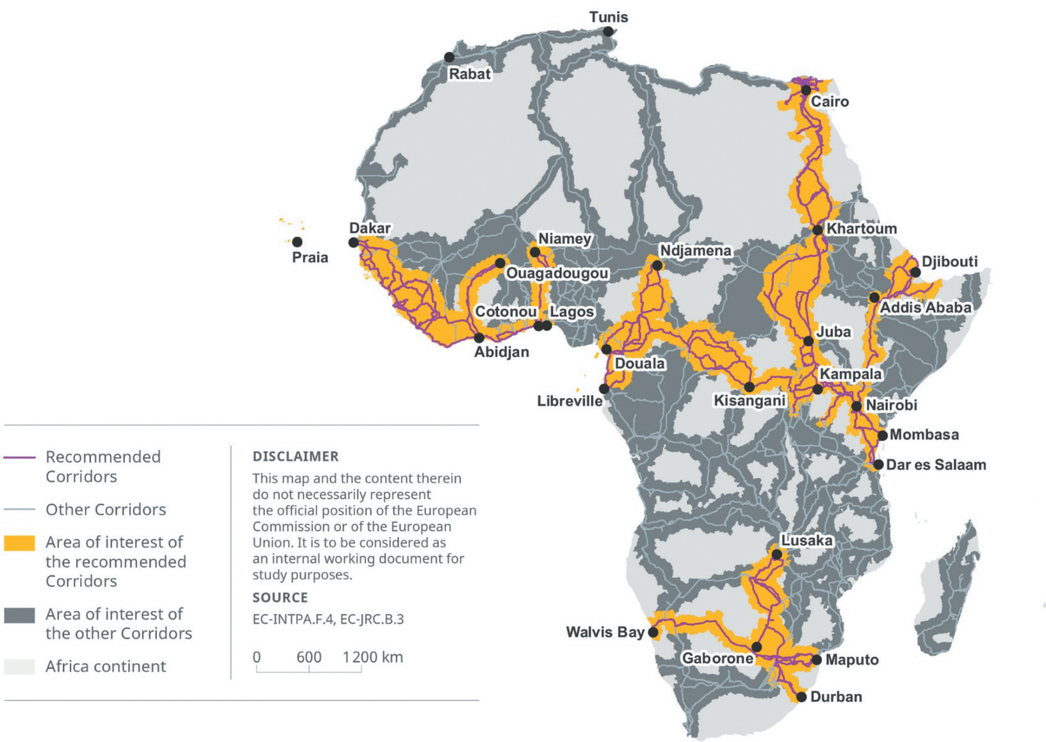

Figure 2. The initially identified 55 Corridors and the final envisaged 11 Strategic Corridors, as emerged from the CUSA project (source [1]).

The user-based weights have been derived along with expert opinions, focusing on selected indicators with particular relevance to the EU–Africa scenario:

- Highest weights: Trade, investments (FDI, EC-financed projects and China investments), air traffic (passengers) and container sea port connections;
- Medium weights: *Presence of mining sites* and conflict-prone areas;
- Lowest weights: Presence of renewable resources, occurrence of floods and educational attainment of women.

2.3. Understanding how Strategic Corridors can support the mineral sector

As a follow-up, a range of possibility for further development emerged, including for identifying specific areas of interventions for each of the selected Strategic Corridors. These might strengthen the corridor efficiency in its multiple dimensions, including, but not limited to, transport performance (costs, time and reliability), socio-economic aspects, logistics and trade development and environmental impact.

In the context of this paper, the initial step focused on spatial analyses related to the present and future (prospective) mine projects. Mining properties were extracted from S&P Global data and assessed whether they fall inside or outside the corridors. The analysis grouped mining properties in two main categories, one representative for active mines and one for exploration activities, the latter considered as an outlook to potential mines of the future.

According to S&P Global data, 4091 mining properties can be georeferenced across Africa: the majority of them are described in terms of development stage and status: few of them lack a designation in terms of either stage (118) or status (131), but all of them are described by at least one of the two attributes.

The current analysis concentrates on mining properties of any stage and status combined, excluding only those that are classified as 'closed' and 'inactive'. For the purpose of this exercise, the remaining properties, 3903 in the whole continent, are further classified into two categories: consolidated and perspective. The first category includes all mining properties that are associated with a 'Production' stage, i.e. Operating, Satellite, Expansion, Limited or Residual, irrespective of their associated status. All other stages, from 'Early-Stage' to 'Preproduction', are included under the second category. Also, mining properties that are reported as 'closed', but not inactive, are retained in this second category.

A certain number of mining properties (27) are of type 'Ocean': they are included in the statistics at Country level, and since they cannot be allocated to any specific Strategic Corridor, they are excluded from the analysis at corridor level.

The number of mining properties that are located in at least one corridor is 1601: their distribution per corridor is reported in Table 2.

For the current elaborations, the considered critical and non-critical raw materials derive from the list of critical raw materials for the EU [17]. The analysis also considered the following four battery materials: cobalt, nickel, lithium and natural graphite.

Mining properties in S&P Global data have been considered according to all commodities reported in the original database.

3. Results

3.1. Main results from CUSA

The first part of CUSA project led to the identification of 55 corridors, in close dialogue with the EU Delegations in Africa, and covering all regions of the continent (Figure 2).

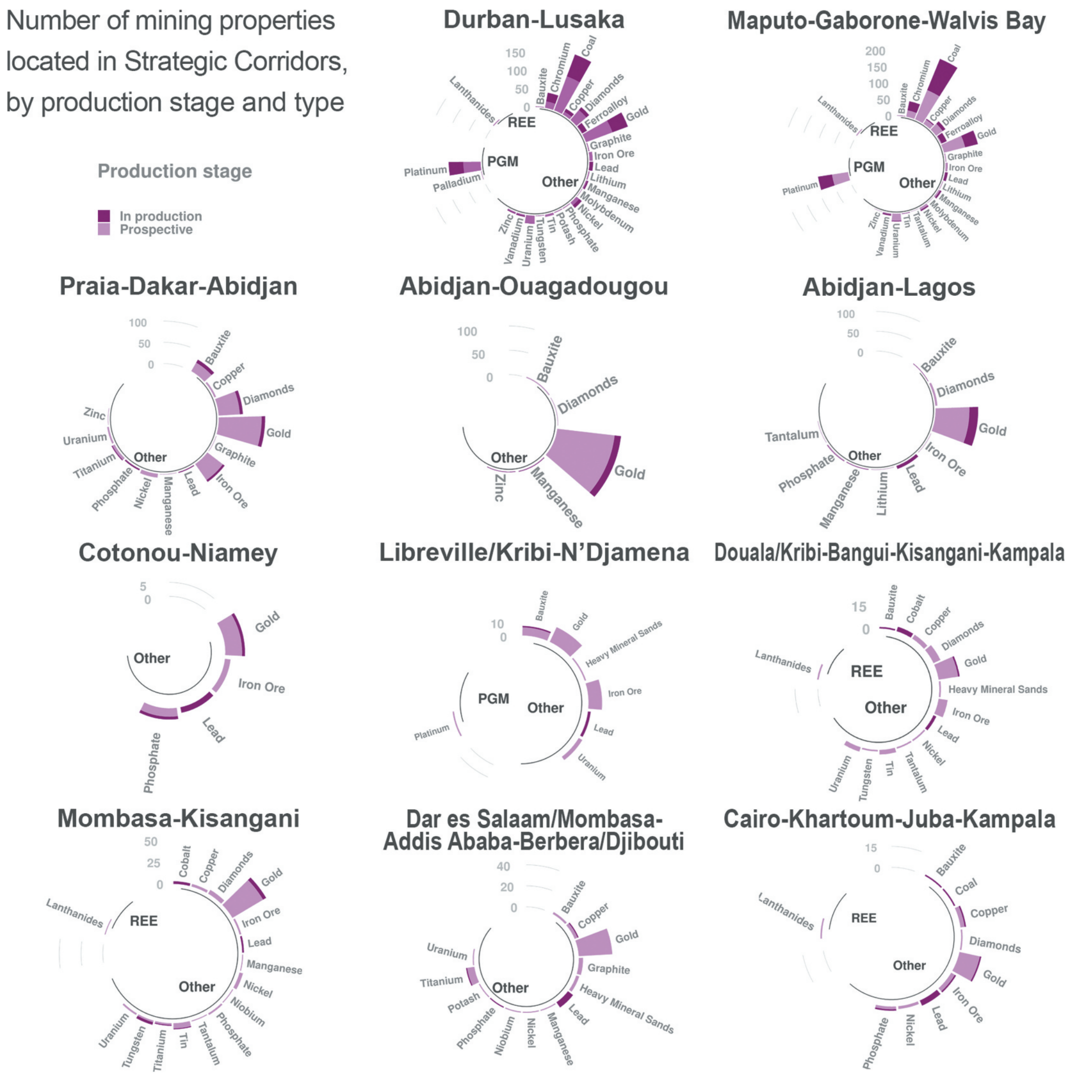

Figure 3. Number of mining properties located in Strategic corridors, by production stage and type.

The characterisation and subsequent multi-criteria analysis, which used the 32 selected quantitative indicators, led to specific rankings of the 55 corridors. In turn, for 31 corridors best scoring in each of the four scenarios, detailed informative fiches have been compiled and used for further scrutiny within the European Commission Services, financial institutions, African Union and other relevant stakeholders. Such a process has further contributed to define the 11 prioritised Strategic Corridors in Africa (Figure 2).

The final recommended corridors would potentially benefit from NDICI investments (Neighbourhood, Development and International Cooperation Instrument), in the form of multi-country Team Europe Initiatives shaped along the Strategic Corridors themselves [22].

3.2. Main results from CUSA as mineral resource corridors

Figure 3 gives an overview of the 11 corridors with an emphasis on the number of mining properties falling inside them. More detailed results are reported in Table 3.

Table 3. Number of mining properties distributed across corridors (source: elaboration from S&P Global data).

	Abidjan-Ouagadougou	Cotonou-Niamey	Praia-Dakar-Abidjan	Abidjan-Lagos	Mombasa-Kisangani	Douala/Kribi-Kampala	Cairo-Khartoum-Juba-Kampala	Libreville/Kribi-N'Djamena	Dar es Salaam/Mombasa-Addis Ababa-Berbera/Djibouti	Durban-Lusaka	Maputo-Gaborone-Walvis Bay
Aggregates	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (1)	- (-)
Aluminium (bauxite)	- (2)	- (-)	8 (23)	1 (-)	- (1)	1 (-)	1 (-)	1 (7)	- (2)	1 (-)	1 (-)
Antimony	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	1 (-)
Beryllium	- (1)	- (-)	- (1)	- (2)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (1)
Cadmium	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (1)	- (-)
Caesium	- (-)	- (-)	- (-)	- (1)	- (1)	- (1)	- (1)	- (-)	- (-)	- (-)	- (1)
Cerium	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (1)
Chromium	- (-)	- (-)	- (2)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	37 (21)	44 (27)
Coal	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	1 (-)	- (-)	- (-)	64 (100)	103 (97)
Cobalt	- (1)	- (-)	- (9)	- (1)	3 (6)	3 (3)	- (3)	- (-)	- (-)	10 (7)	5 (3)
Copper	3 (4)	- (3)	- (15)	- (1)	1 (13)	1 (7)	1 (8)	- (-)	1 (5)	39 (47)	28 (41)
Diamonds	- (1)	- (-)	7 (57)	- (8)	- (5)	- (5)	- (1)	- (1)	- (-)	10 (36)	10 (25)
Dysprosium	- (-)	- (-)	- (-)	- (-)	- (1)	- (1)	- (1)	- (-)	- (-)	- (-)	- (-)
Ferroalloy	- (-)	- (-)	- (1)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	15 (3)	21 (4)
Garnet	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (1)	- (-)	- (-)
Germanium	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (1)	- (-)
Gold	14 (119)	1 (6)	9 (112)	22 (90)	5 (46)	2 (17)	1 (18)	- (13)	- (34)	81 (119)	76 (113)
Graphite	- (-)	- (-)	- (1)	- (-)	- (-)	- (-)	- (-)	- (-)	- (4)	1 (1)	- (3)
Heavy Mineral Sands	- (-)	- (-)	2 (5)	- (-)	1 (2)	- (1)	- (-)	- (1)	1 (10)	- (-)	- (-)
Iridium	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	20 (4)	23 (6)
Iron Ore	- (-)	- (2)	5 (51)	- (1)	- (5)	- (7)	1 (3)	- (11)	- (1)	1 (15)	4 (9)
Iron Sand	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	1 (-)
Lanthanides	- (-)	- (-)	- (4)	- (-)	- (5)	- (1)	- (4)	- (-)	- (1)	- (5)	- (4)
Lead	1 (2)	2 (-)	2 (6)	8 (-)	2 (3)	2 (2)	4 (3)	2 (-)	6 (2)	10 (2)	9 (5)
Leucoxene	- (-)	- (-)	1 (1)	- (-)	- (-)	- (-)	- (-)	- (-)	- (3)	- (-)	- (-)
Lithium	- (1)	- (-)	- (1)	- (3)	- (-)	- (-)	- (-)	- (-)	- (-)	- (5)	1 (3)
Magnesium	- (-)	- (-)	- (1)	- (-)	- (2)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)
Magnetite	- (-)	- (-)	1 (4)	- (-)	- (1)	- (-)	- (1)	- (-)	- (-)	- (1)	1 (-)
Manganese	1 (2)	- (-)	- (2)	1 (3)	- (1)	- (-)	- (-)	- (-)	- (1)	5 (4)	6 (5)
Molybdenum	- (1)	- (-)	- (1)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (1)	- (1)
Neodymium	- (-)	- (-)	- (-)	- (-)	- (1)	- (1)	- (1)	- (-)	- (-)	- (-)	- (-)
Nickel	- (2)	- (-)	- (11)	- (1)	- (5)	- (2)	- (3)	- (-)	- (3)	33 (37)	28 (27)
Niobium	- (1)	- (-)	- (2)	- (2)	- (4)	- (-)	- (1)	- (-)	- (1)	- (2)	1 (1)
Osmium	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	2 (1)	3 (1)
Palladium	- (-)	- (-)	- (4)	- (-)	- (1)	- (-)	- (2)	- (1)	- (-)	39 (66)	40 (61)

(*Continued*)

Table 3. (Continued).

	Abidjan-Ouagadougou	Cotonou-Niamey	Praia-Dakar-Abidjan	Abidjan-Lagos	Mombasa-Kisangani	Douala/Kribi-Kampala	Cairo-Khartoum-Juba-Kampala	Libreville/Kribi-N'Djamena	Dar es Salaam/Mombasa-Addis Ababa-Berbera/Djibouti	Durban-Lusaka	Maputo-Gaborone-Walvis Bay
Phosphate	- (-)	1 (3)	3 (1)	1 (2)	- (2)	- (-)	1 (2)	- (-)	1 (1)	- (2)	- (-)
Platinum	- (-)	- (-)	- (4)	- (-)	- (1)	- (-)	- (2)	- (1)	- (-)	52 (72)	54 (64)
Potash	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (2)	- (5)	- (1)
Praseodymium	- (-)	- (-)	- (-)	- (-)	- (1)	- (1)	- (1)	- (-)	- (-)	- (-)	- (-)
Rhodium	- (-)	- (-)	- (1)	- (-)	- (1)	- (-)	- (1)	- (1)	- (-)	37 (55)	39 (53)
Rubidium	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	1 (-)	1 (1)
Ruthenium	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	- (-)	18 (5)	21 (5)
Scandium	- (-)	- (-)	- (1)	- (-)	- (1)	- (1)	- (1)	- (-)	- (-)	- (1)	- (-)
Silver	8 (2)	- (1)	4 (1)	9 (-)	1 (6)	- (2)	- (2)	- (-)	- (1)	13 (11)	11 (21)
Tantalum	- (1)	- (-)	- (2)	- (4)	- (4)	- (1)	- (-)	- (1)	- (-)	- (4)	1 (3)
Terbium	- (-)	- (-)	- (-)	- (-)	- (1)	- (1)	- (1)	- (-)	- (-)	- (-)	- (-)
Thorium	- (-)	- (-)	- (-)	- (-)	- (1)	- (1)	- (1)	- (-)	- (-)	- (-)	- (-)
Tin	- (-)	- (-)	- (-)	- (1)	1 (6)	- (3)	- (-)	- (-)	- (-)	- (8)	1 (4)
Titanium	- (-)	- (-)	5 (12)	- (-)	2 (5)	- (2)	- (1)	- (2)	2 (21)	- (4)	1 (4)
Tungsten	- (-)	- (-)	- (-)	- (-)	3 (5)	- (2)	- (-)	- (-)	- (1)	1 (1)	- (2)
Uranium	- (-)	- (-)	- (8)	- (-)	- (3)	- (4)	- (1)	- (3)	- (2)	10 (30)	11 (32)
Vanadium	- (-)	- (-)	- (-)	- (-)	- (1)	- (-)	- (1)	- (-)	- (-)	4 (10)	4 (9)
Zinc	1 (2)	- (1)	- (7)	- (-)	- (5)	- (2)	- (3)	- (-)	- (2)	3 (6)	- (6)
Zircon	- (-)	- (-)	2 (5)	- (-)	1 (2)	- (1)	- (-)	- (1)	1 (9)	- (-)	- (-)

**Closed and inactive sites are excluded. The first figure indicates mines in production. The figure within parenthesis refers to prospective mines (properties).*
*** Note: a mining property can be associated with more than one corridor in case it is located in an area of overlap between two or more corridors.*
**** A single mining property can be associated with more than one commodity.*

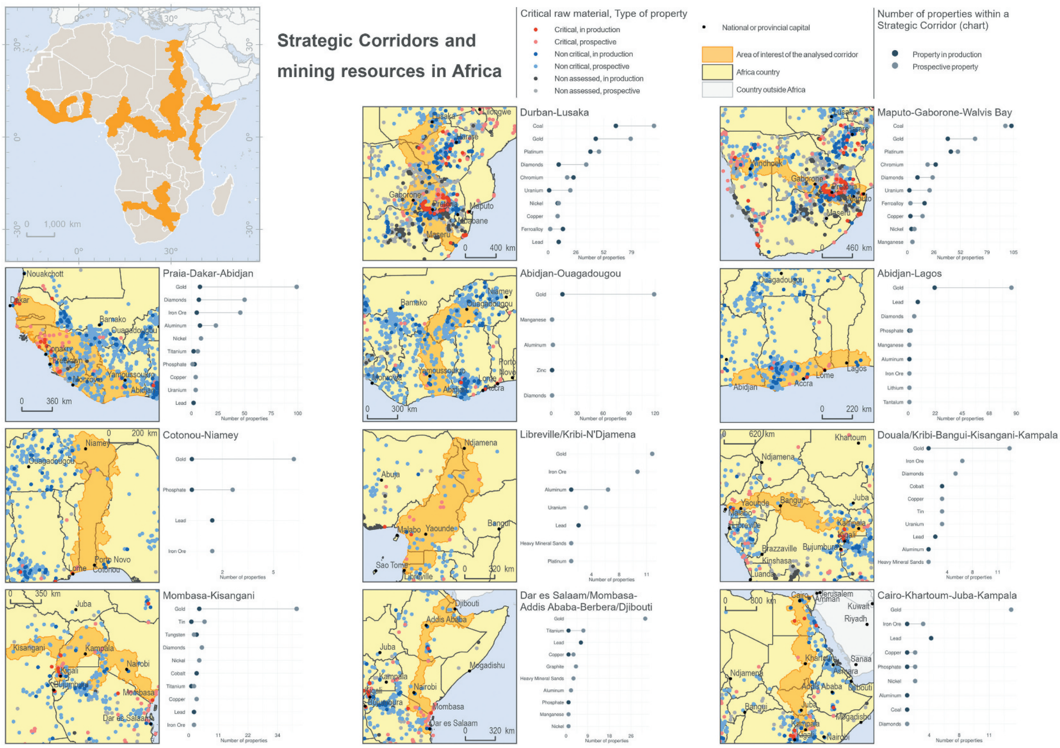

Figure 4. Strategic Corridors and mining resources in Africa.

At a glance, some corridors look particularly rich in type of commodities and number of related mining properties, e.g. Durban-Lusaka and Maputo-Gaborone-Walvis Bay, while other corridors show opposite results, e.g. Cotonou-Niamey.

Figure 4 maps the overlap between the 11 corridors and mining properties, with an emphasis on critical raw materials. In the context of the current paper, the bar charts of Figure 4 report the number of mining properties only, in view of future and more detailed analyses in which, for narrower target areas, it will be possible to better investigate on the size of deposits, possible volumes of production and interlinks with the related infrastructures for energy, transport and water, among others.

Figures 5 and 6 zoom on two corridors with substantial current and potential future mines, including for battery materials, which clearly shows that in the case of Durban-Lusaka and Maputo-Gaborone-Walvis Bay Strategic Corridors are also mineral corridors.

On the contrary, Figure 7 highlights one example in which the role of Strategic Corridors as mineral resource corridors seems marginal, at least based on this level of knowledge.

The supplementary information shows the same visual analysis for the remaining eight corridors.

Table 4 reports the distribution of mining properties across African regions and Strategic Corridors. The analysis shows that in two regions, Southern and West, nearly half (49%) of the mining properties fall inside one corridor at least. In the case of the Northern and Central regions, only 12% and 15%, respectively, of the mining properties fall inside at least one corridor. The East region features 24% of the mining properties included in corridors. As a reference term, the total area covered by all the 11 Strategic Corridors is around 18% of the African continent.

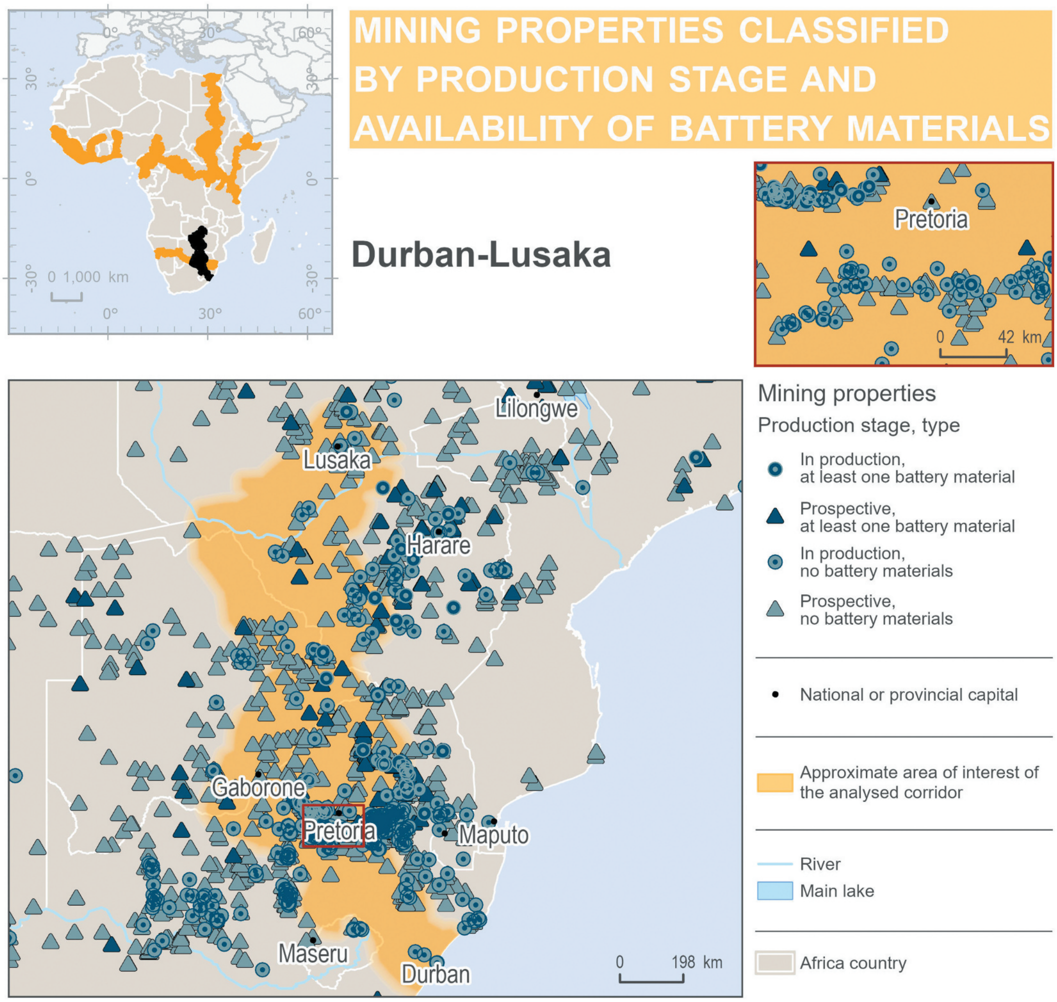

Figure 5. Mining properties classified by production stage and availability of battery materials: Durban-Lusaka.

4. Discussion

The requirements of the study in support to the selection of EU–Africa Strategic Corridors and the wide range of topics to cover made it necessary to deal with very diverse data sources and, as a consequence, input data with different characteristics as to the criteria listed above. Data and indicators where therefore selected to make them compatible in terms of quality and accuracy, also filling data gaps by using data fusion techniques.

Conversely, in the investigation on Strategic Corridors as mineral resource corridors, only one data source was identified with continent-wide coverage and adequate spatial resolution: S&P Global data. Even though the initial assessment was possible and the results appeared to be consistent with the stated objectives, for more in-depth and quantitative analyses also other sources should be considered, as well as the scale of investigation should be narrowed to single corridors or sub-corridors. In fact, only at a lower scale, it would be possible to better understand how mineral resources can act as a catalyser to create and strengthen value chains and territorial organisation, in turn boosting economic and societal development at regional or higher scale.

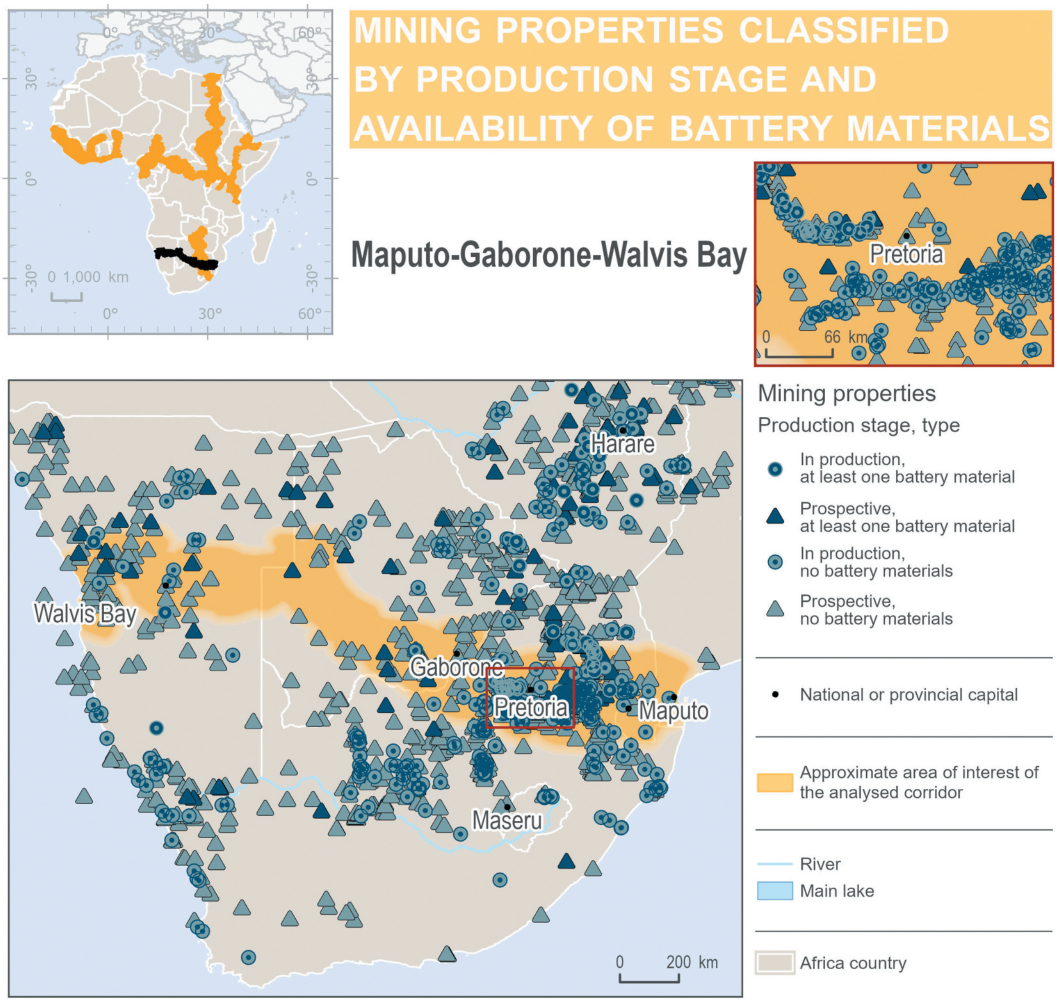

Figure 6. Mining properties classified by production stage and availability of battery materials: Maputo-Gaborone-Walvis Bay.

Table 4. Distribution of mining properties across African regions and Strategic Corridors (source: elaboration from S&P Global data).

Region	Mining properties (number)	Mining properties in at least one corridor (number)	Mining properties in at least one corridor (%)
Central	349	54	15
East	877	210	24
Northern	142	17	12
Southern	1465	720	49
West	1070	525	49

Nonetheless, 5 of the 11 Strategic Corridors seem to also be mineral resource corridors, as 49% of mining properties fall inside them: Durban-Lusaka and Maputo-Gaborone-Walvis Bay in the Southern Region and Praia-Dakar-Abidjan, Abidjan-Lagos and Abidjan-Ouagadougou in the Western region. Some of the other corridors show several mining properties in the close neighbourhood, so that the initial results shown in this paper might be used as a starting point for future expansion of the corridors or parallel initiatives. Also, the presence of several mining properties associated with battery materials encourages future investigation.

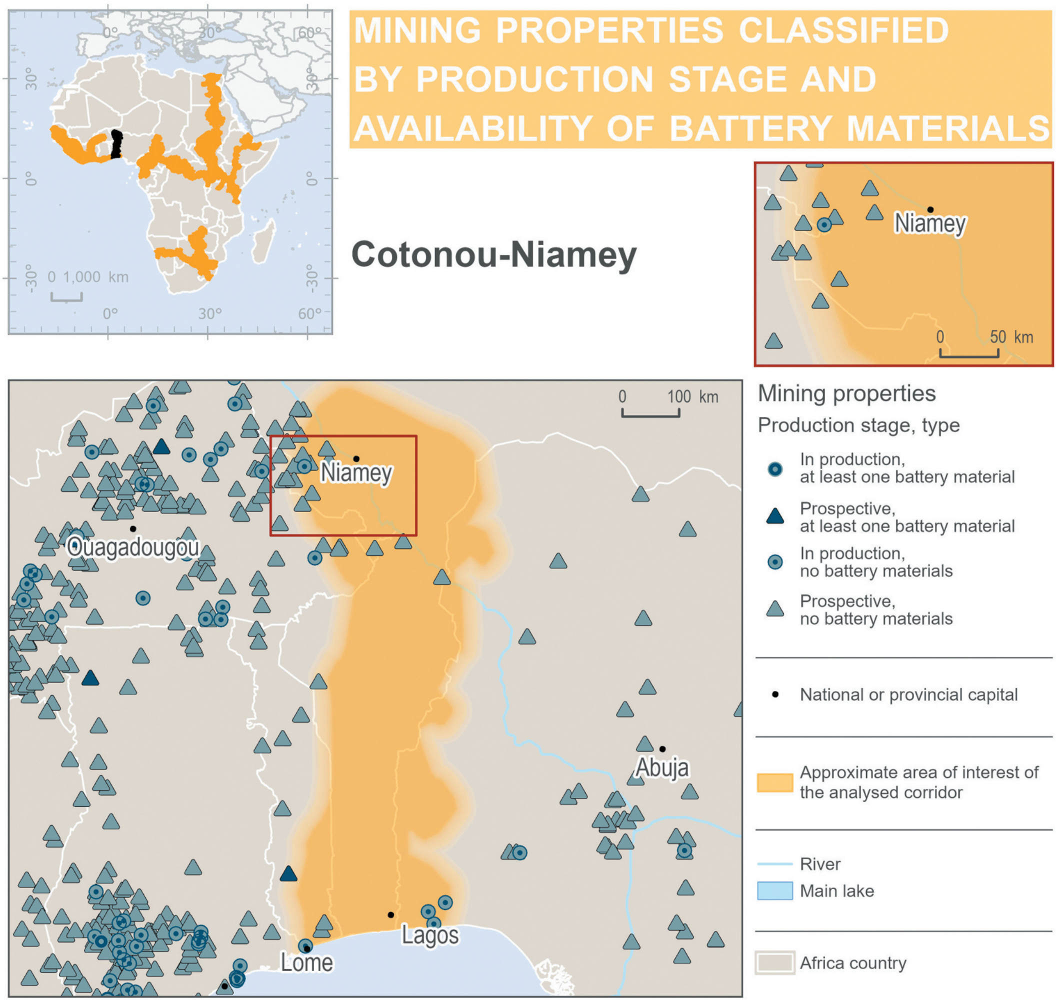

Figure 7. Mining properties classified by production stage and availability of battery materials: Cotonou-Niamey.

The only corridor across the Northern region, Cairo-Khartoum-Juba-Kampala, can be taken as an example of limited coverage by S&P Global data, which again suggests to use multiple data sources in future assessments.

5. Conclusions

The methodology, developed in the CUSA project and discussed in this paper, constituted a novelty in the way Strategic Corridors and urban systems were defined and mapped, characterised and assessed using quantitative approaches. These approaches, coupled with the extensive consultations with various stakeholders, guaranteed the objectivity and transparency of the whole process. The evidence produced could therefore support decision-makers in the final selection of Strategic Corridors.

Based on the current results at continent-wide scale, it can be concluded that at least five EU–Africa Strategic Corridors can also be considered as mineral resource corridors. Corridors, in fact, facilitate access to current and potential future mines by providing transport and energy infrastructures, among others, and, in turn, put the related mineral industries in the context of a stronger and more strategic territorial organisation focused on economic and social development at regional or higher scale.

Even though a general conclusion can be drawn on the fact that EU–Africa Strategic Corridors certainly contribute to mitigate the risk of supply disruptions of Critical Raw Materials for the EU, further investigation is needed, in narrowed and targeted areas and using multiple data sources, to identify future potential flows of mineral commodities and quantify the related risk mitigation factors.

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Disclosure statement

The authors are responsible for the content, which does not necessarily reflect the views of the European Commission.

ORCID

Claudia Baranzelli http://orcid.org/0000-0002-6032-7051
Gian Andrea Blengini http://orcid.org/0000-0002-7977-1363

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