Data Driven Approach to Enhancing Efficiency and Value in Healthcare

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Chapter 3

Analysis of healthcare activity, capacity and demand

This chapter presents two examples of use of modelling and simulation as a tool to evaluate different strategies to manage the increasing demand for healthcare services, to increase the utilisation of the current capacity, and to understand bottlenecks and constraints across the system.

This chapter is structures as follows: Section 3.1 introduces a project part of a programme to increase early detection of cancer and thereby reduce premature mortality in England; Section 3.1.0.1 summarises statistics for cancer incidence and mortality worldwide, and introduces the UK bowel cancer screening programme; Methodology is presented in Section 3.1.1; Analysis of activity, capacity and demand, and results are discussed in Section 3.1.2; Conclusions are presented in Section 3.1.3. Section 3.2 summarises a study focuses on the prediction the burden of revision knee arthroplasty in Spain.

3.1 Modelling the colorectal cancer diagnostic services pathway

3.1.0.1 Introduction

Analysis of activity, capacity and demand is a key component of improvement of healthcare systems so that patients do not have an unnecessary wait for diagnostic or

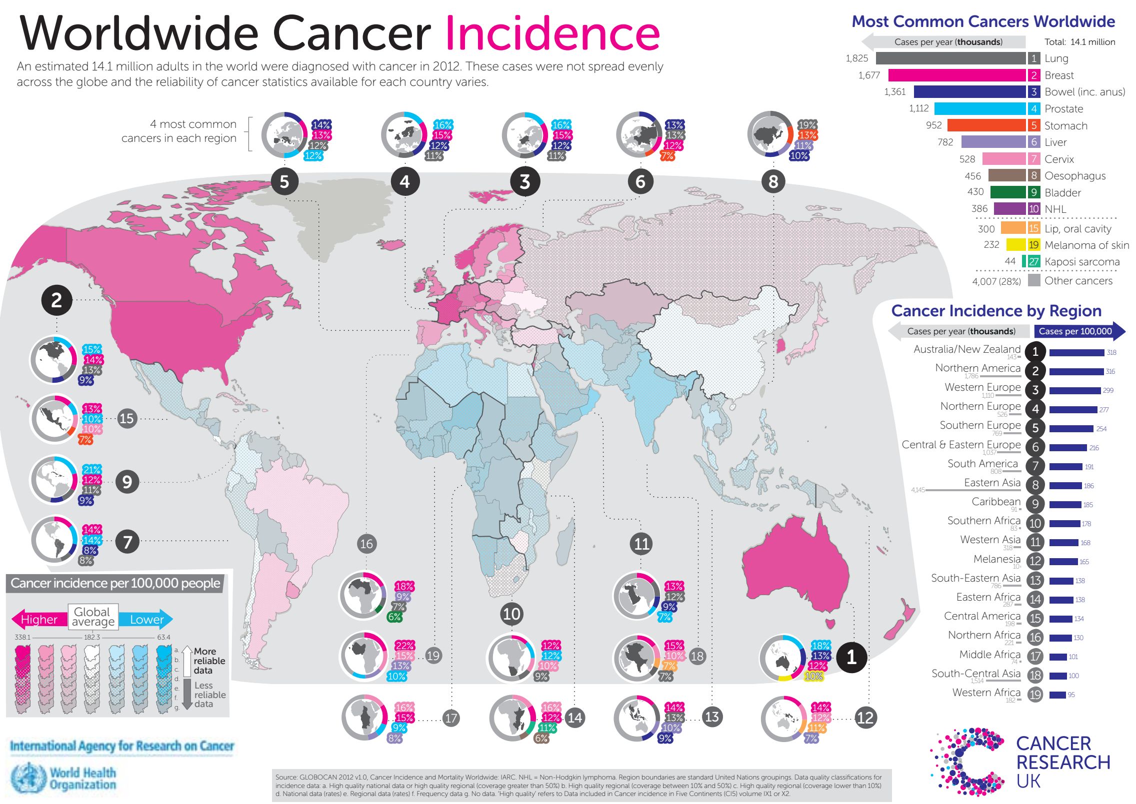

Figure 3.1: Map of cancer incidence worldwide (2014). Credit: Cancer Research UK.

treatment. The discrepancy between capacity and demand is one of the main factors involves in the growing waiting lists for healthcare services.

Statistics from Cancer Research UK [30] shows that in 2012, an estimated 14.1 million new cases of cancer occurred, and an estimated 8.2 million people died from cancer cancer worldwide. The four most common cancers occurring worldwide are lung, female breast, bowel and prostate cancer. These four account for around 4 in 10 of all cancers diagnosed worldwide. Lung, liver, stomach, and bowel are the most common causes of cancer death worldwide, accounting for nearly half of all cancer deaths. Figure 3.1 shows a map with cancer incidence worldwide. Figure 3.2 shows cancer mortality worldwide.

Bowel cancer is also called colorectal cancer and some data include anal cancer. The International Classification of Diseases (ICD) codes for bowel cancer incidence and mortality are ICD-10 C18-C20 (which includes cancers of colon, rectum and rectosigmoid junction). The ICD code for bowel cancer survival are ICD-10 C18-C20 and C21.8. The ICD code for colon cancer is ICD-10 C18. The ICD codes for rectal

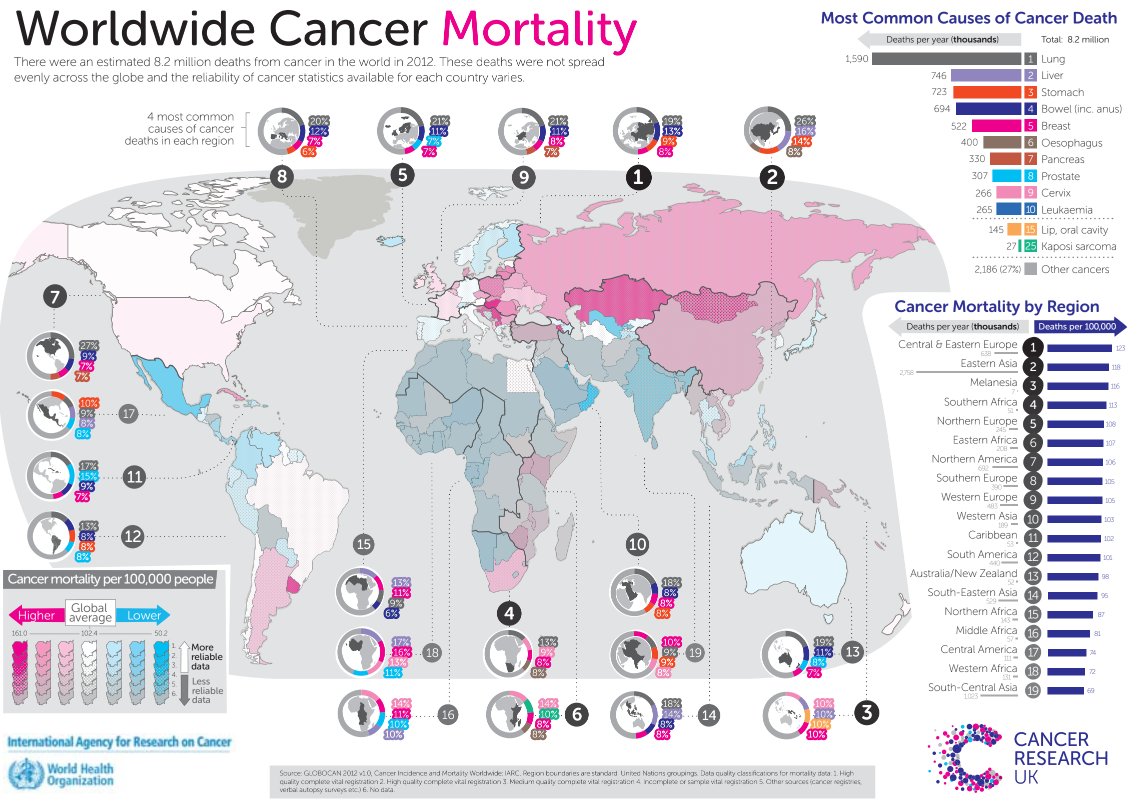

Figure 3.2: Map of cancer mortality worldwide (2014). Credit: Cancer Research UK.

cancer are ICD-10 C19-C20 and C21.8.

In the UK, bowel cancer is the fourth most common cancer, around 41,300 new cases of bowel were diagnosed in 2014, accounting for 12% of all new cases. Over half of bowel cancer cases are diagnosed at a late stage in England (2014). Bowel cancer was the second most common cause of cancer death in the UK in 2014, accounting for 10% of all cancer deaths. Around 15,900 bowel cancer deaths were registered in the UK in 2014 [29].

When diagnosed at its earliest stage, more than 90% of the patients with bowel cancer will survive their disease for five years or more, compared with less than 10% when diagnosed at the latest stage [29].

To detect cases of bowel cancer at its earliest stage, the NHS offers two bowel cancer screening programmes:

- FOB test. Faecal Occult Blood (FOB) test is offered every two years to patients aged 60-74.

- Bowel Scope Screening. Offered to people at the age of 55, involves a Flexible sigmoidoscopy (FS).

The impact of the bowel cancer screening programme in the demand for endoscopy procedures was analysed as part of this study.

3.1.1 Methodology

This project was developed working in collaboration with the University of Southampton, the Wessex Academic Health Science Network (AHSN), and NHS England. The work aims to increase early detection of cancer and thereby reduce premature mortality in the Wessex region in southern England, UK. NHS Trusts and NHS Clinical Commissioning Groups (CCGs) across the region.

This work was identified as a priority work-stream by the NHS Wessex Strategic Clinical Network and agreed as such by the Wessex CCGs through the Commissioning Assembly. NHS CCGs were created following the Health and Social Care Act in 2012 [163], the most extensive reorganisation of the structure of the NHS in England to date, and replaced Primary Care Trusts on April 2013. CCGs are clinically-led statutory NHS bodies responsible for the planning and commissioning of healthcare services for their local area. NHS Trusts are providers delivering NHS-funded care.

At a regional level, a Discrete Event Simulation (DES) model of the Bowel Cancer Screening Programme for the South of England was produced, as well as the modelling of endoscopy capacity, activity and demand across the region. Future demand for endoscopy services in five years time was estimated using a simulation model. At the local level, bespoke endoscopy service modelling was produced.

Figure 3.3 presents the Wessex region in England. Figure 3.4 shows the hospitals included in the analysis, as well as the number of endoscopy rooms currently available by provider.

The project was managed by NHS England in Wessex. A multi-disciplinary working group was established, chaired by a consultant colorectal surgeon, and consisting of primary and secondary clinicians, healthcare managers and commissioners to oversee the undertaking of this project. We leaded the project design and development, data collection and analysis, simulation modelling, and presentation of the results to hospitals and commissioners, as well as NHS bodies across the country.

Information about Screening Programmes was provided by the Bowel Cancer Screening Southern Programme Hub, including screening activity from 3 Local Screening Centres, uptake, positivity, and clinical outcomes between 2012 and 2014. Flexi-

Figure 3.3: The Wessex region in Southern England, UK.

ble Sigmoidoscopy data was extracted from latest NHS Bowel Scope Screening pilot programme in the UK.

Information about endoscopy activity, capacity and demand was requested to each hospital. Population demographic data and cohort life expectancy tables was provided by the Population Statistics Division, part of the Office for National Statistics (ONS), UK. Standard workload measures were taken from the British Society of Gastroenterology (JAG). Detailed assessment of working practices including utilisation rates were made at two Wessex NHS providers.

Figure 3.4: Hospitals in Wessex included in the analysis. The current number of endoscopy rooms by provider is shown in the circle next to each named hospital.

All the significant providers were contacted, including 14 units. Most recent activity data was provided from April 2014 to March 2015. Timetable of session planned was also requested to the department managers.

The British Society of Gastroenterology (BSG) specifies weightings for each Gastrointestinal endoscopic procedure, reflecting their average duration. 1 point typically equates to a 20 minute procedure. The national standard is 12 points per list.

The workload was converted to units of time (20 minutes per endoscopy point) to standardise the analysis, and the patient's case-mix was reflected in type of procedures (e.g. Colonoscopy 2/3 points, Flexisigmoidoscopy 1/2 points, Gastroscopy 1/2 points).

Procedures were differentiated between those for diagnostic or therapeutic purposes, as well as training or service purposes, due to the different time required.

3.1.2 Analysis and results

3.1.2.1 Activity

Figure 3.5 shows the procedures per way performed by endoscopy unit in Wessex. It can be seen from the graph that the providers vary in scale enormously with four large acute hospitals and two very small community hospitals in terms of endoscopy

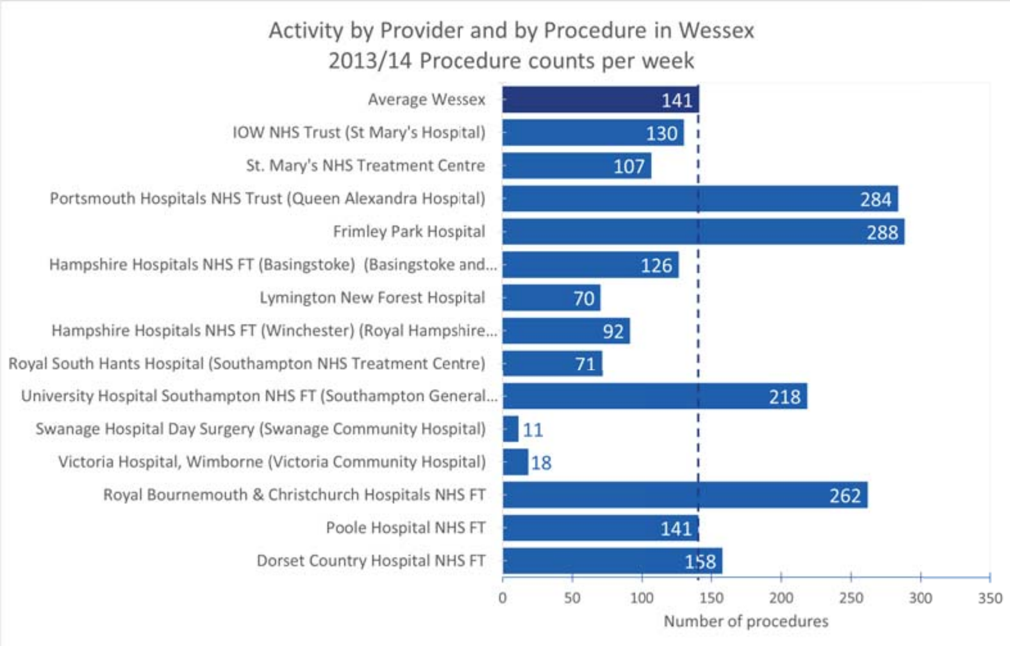

Figure 3.5: Activity by endoscopy unit in Wessex. Number per week.

activity. Data shows absolute values from the providers information. Figure 3.6 summarises the activity by endoscopy unit in term of weekly procedures per room. The graph shows that when the activity is divided across the numbers of rooms at each provider, the range of activity falls between 23 and 65 procedures per room per week, excluding the two smallest units. Finally, Figure 3.7 shows the proportion of procedure type by provider, translated into endoscopy points.

Total endoscopy activity in Wessex was estimated based upon the providers' actual scheduling. For example the smallest provider operates its endoscopy unit 2 sessions per week, the largest provider operates 3 sessions per day, five days per week plus some weekend sessions. Figure 3.8 shows an example of the impact of different endoscopy appointment scheduling systems in four hypothetical hospitals.

Results of the analysis shows that the total endoscopy activity in Wessex between 2013 and 2014 was 3,440 points per week, with an average endoscopy room utilisation of 69% (utilisation varies from 41% to 94%), and an average points by endoscopy list of 8.5%.

3.1.2.2 Capacity

An estimation of the current and potential endoscopy capacity for all Wessex was developed. Current capacity was quantified using the appointment scheduling system

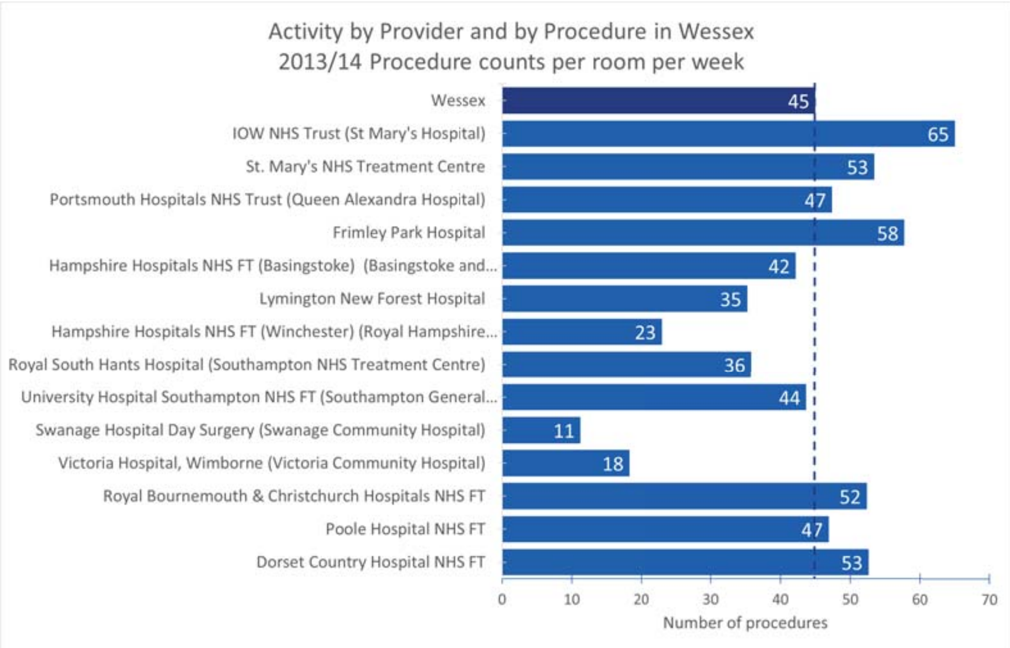

Figure 3.6: Activity by endoscopy unit in Wessex. Number per room per week.

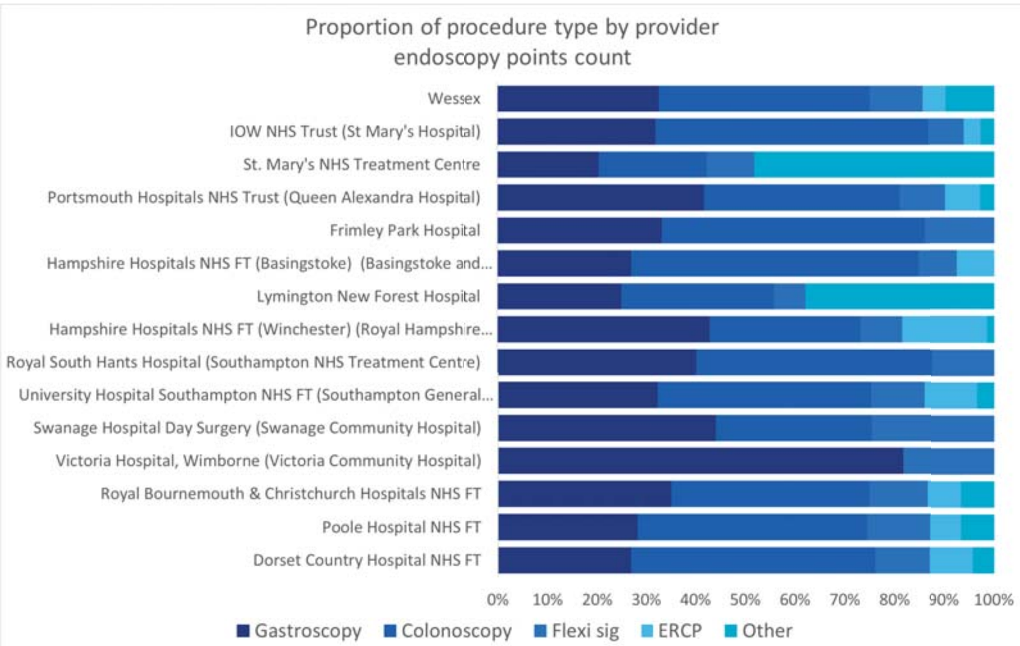

Figure 3.7: Activity by endoscopy unit in Wessex. Proportion of procedure type by provider, endoscopy points count.

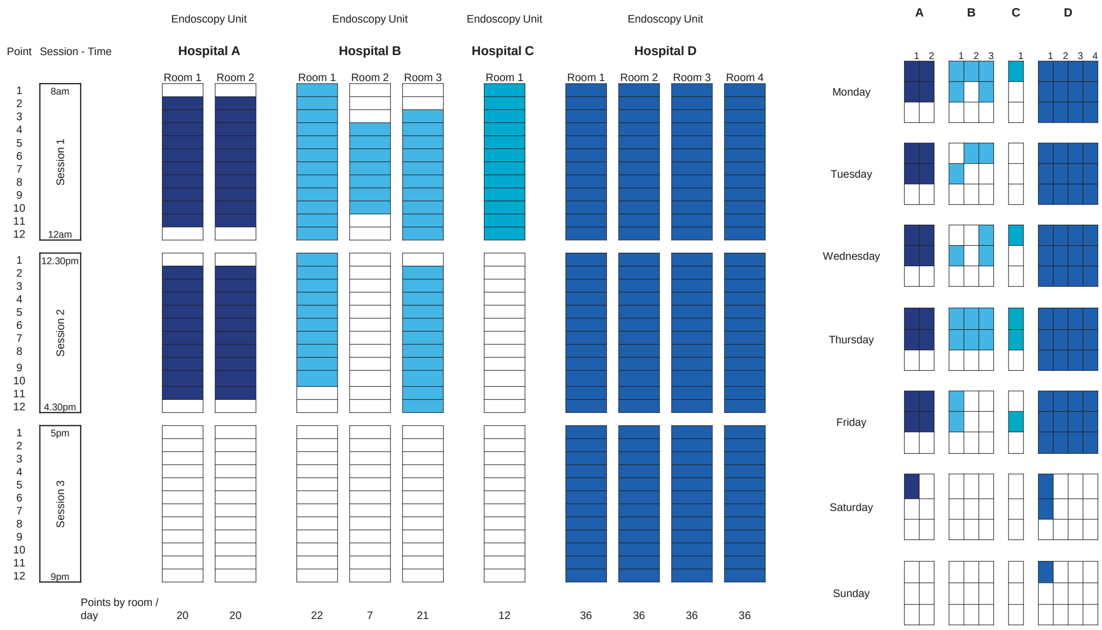

Figure 3.8: Example of appointment scheduling in four hypothetical endoscopy units. Hospital A works with a system based on 2 endoscopy rooms, 10 points per session, 2 sessions per day, Monday to Friday, and 1 session on Saturday morning. Hospital B uses a different system, with 3 rooms, 2 sessions per day and different schedules on a daily basis. Hospital C is a hospital with 1 room running 1 morning session per day Monday and Wednesday, 2 sessions on Thursday and 1 session on Friday afternoon. Hospital C represents a unit running 3 sessions per 3, with 4 endoscopy rooms, and a full 12 points per session system.

reported for each NHS Trust and based on existing working practices. Potential maximum capacity was estimated based on the scenario of 2 sessions per day, 5 days per week, and 12 points per list. One of the Trusts involves in the project is actually testing the implementation of 7 days per week and 12 points per list system, and then a theoretical maximum capacity based on this system was also estimated. Detailed evaluation of the additional staff required with this model was excluded from the analysis as required for the project steering group.

Based on the scenarios described above, the estimated current endoscopy capacity in Wessex is 4,473 points per week. Maximum capacity based on 2 sessions per day and 5 days a week is 5,280 points. Finally, the theoretical maximum capacity based on the 7 days a week system is 11,088 points per week.

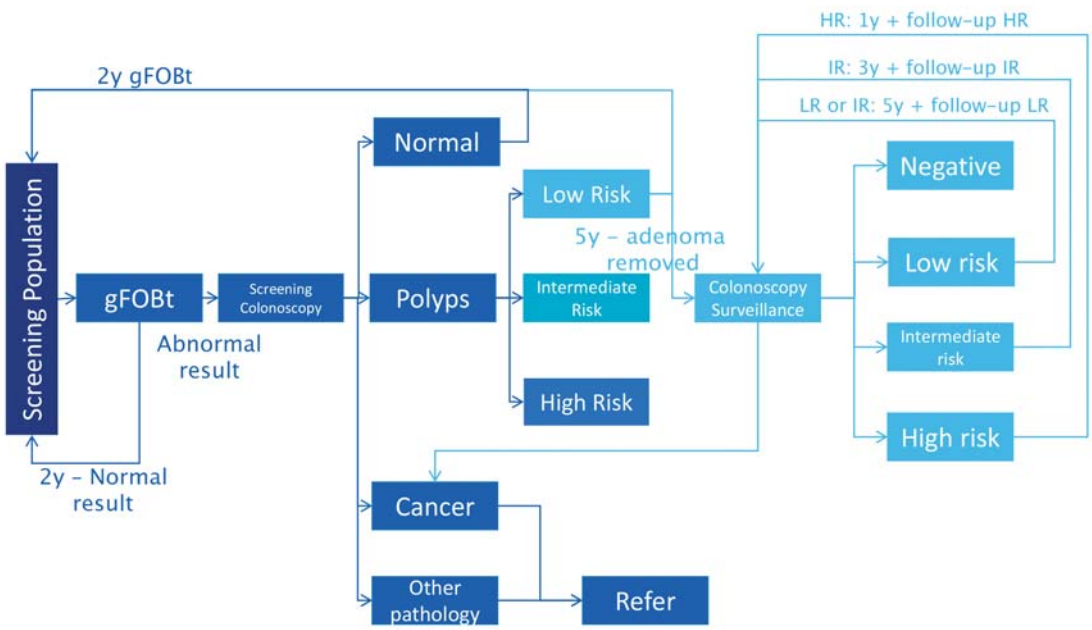

Figure 3.9: Conceptual model for the FOBt Bowel Cancer Screening Programme in the UK. Low risk patients.

3.1.2.3 Demand

Demand for endoscopy procedures is increasing due to a number of factors. One of them is the ageing population, i.e., increase in both the number of older people and them living longer. NHS performance targets, e.g. the NHS Operating Framework expectation that less than 1% of patients should wait more than six weeks for diagnostic tests. Introduction of the Flexible Sigmoidoscopy Bowel Cancer Screening Programme (BCSP) for people when they reach the age of 55 which can be requested up to the age of 60. The faecal occult blood testing (FOBT) screening programme including people aged 60-69 and aged 70-75.

Figures 3.9, 3.10, 3.11 shows conceptual model for the FOBt Bowel Cancer Screening Programme in the UK. Three pathways are presented for patients with adenomas after an abnormal gFOBt result. The first figure shows the pathway for low risk patients, invited for another gFOBt after two years, and to a surveillance colonoscopy after 5 years of the adenoma removed. Second figure shows the pathways for intermediate risk patients, invited to a surveillance colonoscopy after three years. The final figure presents the pathway for high risk patients, invited for a colonoscopy after a year of the screening test.

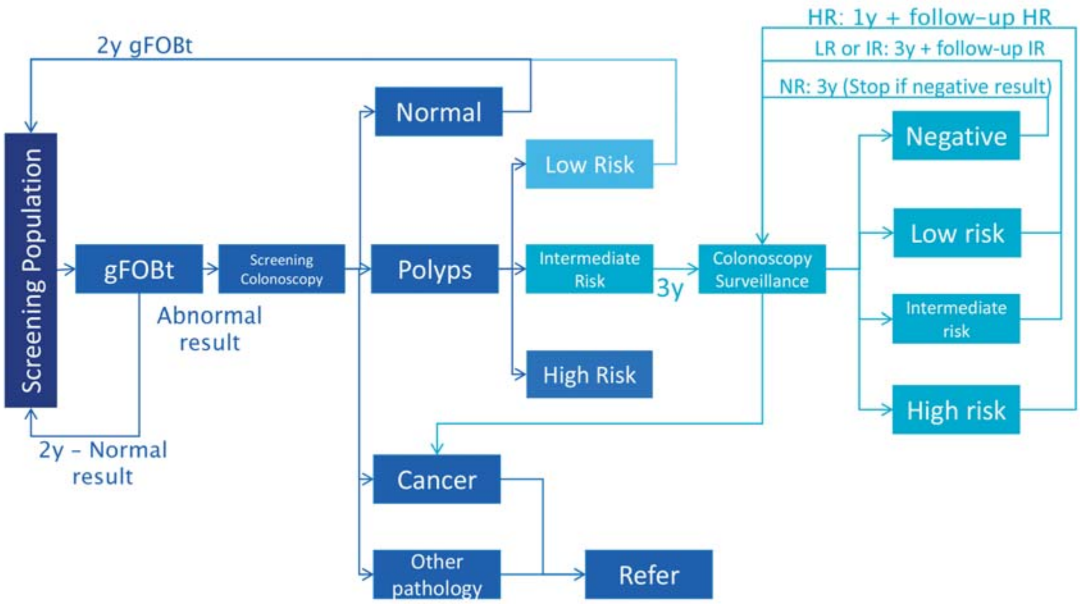

Figure 3.10: Conceptual model for the FOBt Bowel Cancer Screening Programme in the UK. Intermediate risk patients.

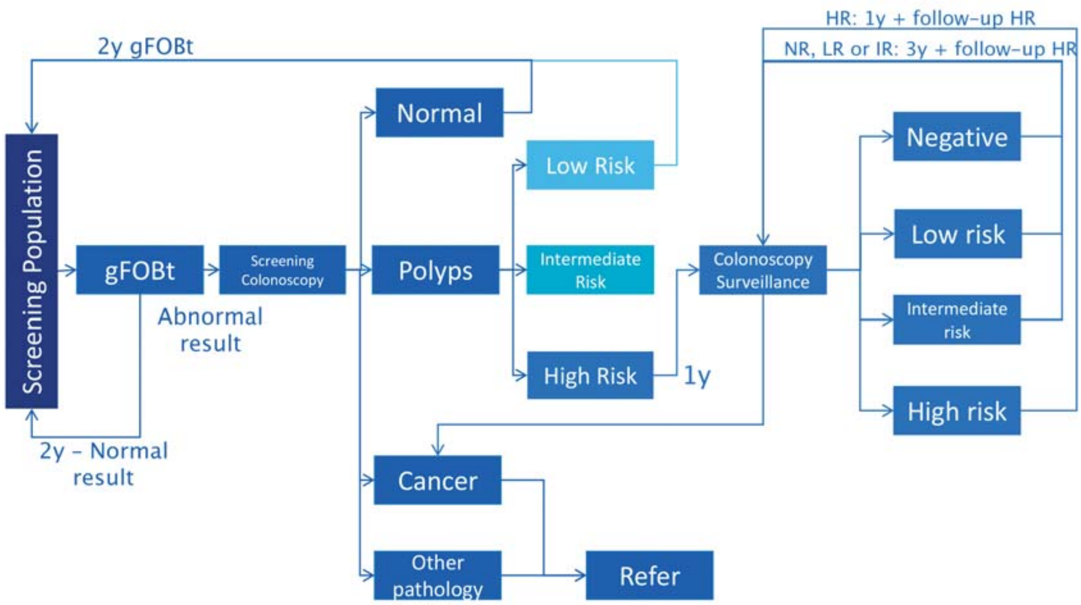

Figure 3.11: Conceptual model for the FOBt Bowel Cancer Screening Programme in the UK. High risk patients.

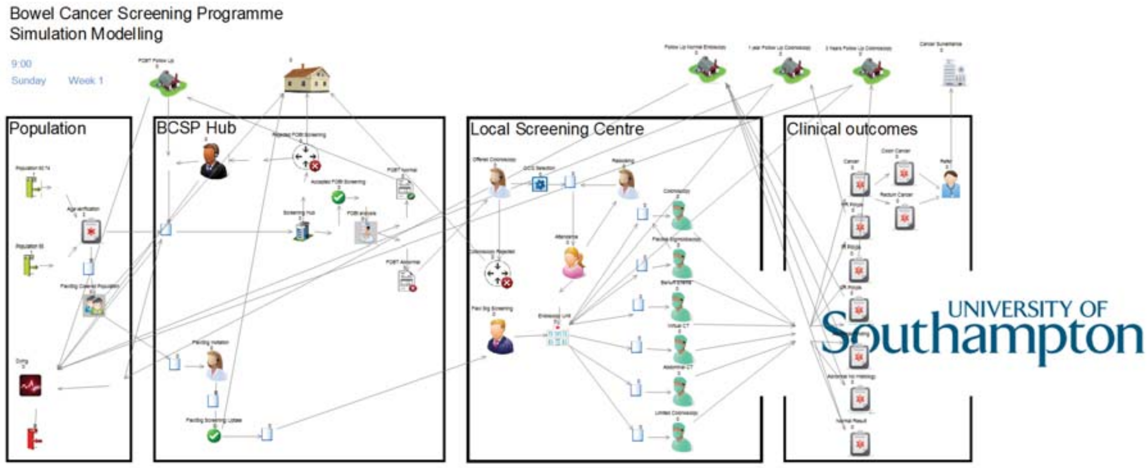

Figure 3.12: Simulation model for a bowel cancer screening programme in the UK.

A simulation model was developed to evaluate the impact of different what-if scenarios in the demand for endoscopy procedures, and a five years projection (2014-2019) of endoscopy demand across Wessex was developed using the model. Figure 3.12 shows the implementation of the simulation model.

Using different cohorts of population, the model was used to evaluate the impact of the screening interventions, including the Bowel Scope Screening, in the demand for colonoscopy and flexible sigmoidoscopy in the South of England and across the Wessex region.

Results of the simulation shows an expected increase of 4% average in the rate (Colonoscopy + Flexible Sigmoidoscopy)/Total number of Endoscopy in the next five years in Wessex based on the FOBt bowel screening programme. The scenario of FOBt bowel screening programme and Bowel Scope screening programme (Flexible Sigmoidoscopy), with 100% of the patients 55 years old invited to the screening, and 50% uptake, the expected increase is 28% average.

Figure 3.13 summarises the analysis of current endoscopy activity and capacity in Wessex, and the estimation of potential capacity and future demand for endoscopy procedures. A detailed analysis at the provider and CCGs level was also performed as part of this project, the results are not presented in this thesis.

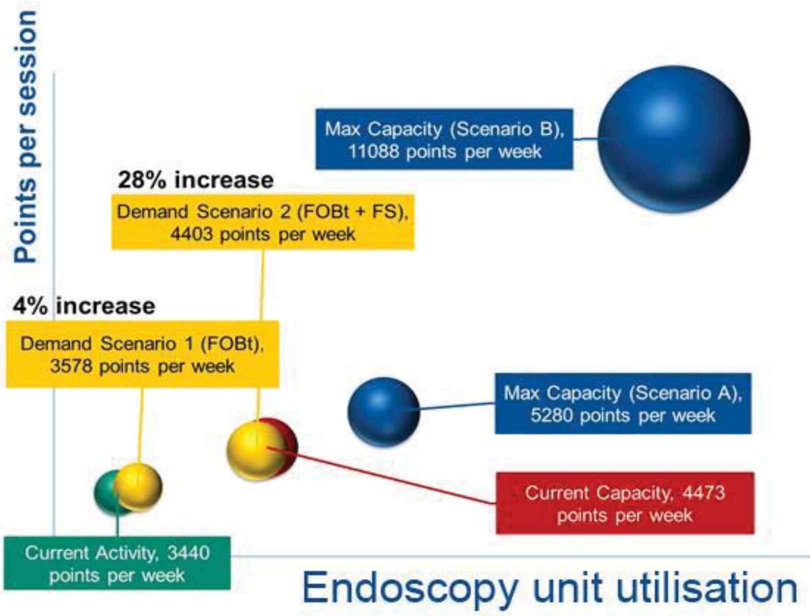

Figure 3.13: Current endoscopy activity, current and maximum capacity, and predicted future demand in Wessex.

3.1.3 Conclusions

Working with the University of Southampton, Wessex Academic Health Science Network (AHSN), and NHS England, several analysis were performed. The aim was to quantify existing capacity and activity for all Wessex, and also to estimate the potential capacity using the endoscopy rooms available at the hospitals. Finally, a 5 years projection of future demand and capacity needed.

A combination of statistics, data analytics and modelling and simulation, using Discrete Event Simulation approach, was developed to estimate the future demand based on two scenarios. The fist scenario is based on a national bowel cancer screening programme using the fecal occult blood test (FOBt) for screening and a colonoscopy after a negative result. Results of the simulation shows that a 4% increase in demand is expected. In the second scenario analysed, the screening programme is a combination of the FOBt and the new Bowel Scope screening programme (BCSP), based on a Flexible Sigmoidoscopy test for all the patients 55 years old. The expected increase in demand with this scenario is 28%.

An important variation in working practices and efficiency was observed across the region, with an endoscopy room utilisation that varies from 41% to 94% across the hospitals included in the analysis.

The analysis shows a potential to increase capacity within existing resources increasing the number of endoscopy points per session and increasing the room utilisation. An example of the impact of this interventions is that all the hospitals adopt a 11 points per session policy, and increase the utilisation rate to 80% then the capacity across the region will increase about 12.5%. If activity goes as planned for the hospitals, then an increase from 3,440 points per week (current activity) to 4,473 points per week (current capacity) is possible with all scheduled activity takes place, and no changes to staffing nor session time required.

Following this project, the development of bespoke analysis and modelling for each provider unit was recommended for the project steering group. Another recommendation was the review of current booking templates across sites to understand the variation from the 12 points national standard, and the time assigned to 1 endoscopy point because some units assign 15 minutes and some assign 20 minutes to the same procedure. Review of session utilisation and start and finish times should be routinely monitored as low utilisation usually falls into three categories: insufficient backfilling of lists, high percentage of patient do not attending, and under booking.

3.2 Predicting the burden of revision knee arthroplasty: simulation of a 20-year horizon

This section presents the summary of a publication derived from one of the project developed as part of this thesis and presented in the Appendix A. Appendix B includes the Supplementary Materials.

The study was part of a collaboration between the IMIM (Hospital del Mar Medical Research Institute, Barcelona) and the Agency of Health Quality and Assessment of Catalonia (Agència de Qualitat i Avaluació Sanitàries de Catalunya [AQuAS], Barcelona).

The project was developed to estimate future utilisation scenarios of knee arthroplasty (KA) revision in the Spanish National Health System in the short-term (2015) and long-term (2030) and their impact on primary KA utilisation.

Knee arthroplasty or knee replacement is a surgical procedure to replace the weight-bearing surface of the knee joint in order to relieve the pain and disability of osteoarthritis. It may also be performed for other knee diseases such as rheumatoid arthritis.

A Discrete Event Simulation (DES) was developed to represent KA utilisation for 20 years (2012-2031) in Spain. Data on KA utilisation from 1997 to 2011 was extracted from the minimum data set. Three scenarios of future utilisation of primary KA (1, fixed number since 2011; 2, fixed age and sex adjusted rates since 2011; and 3, projection using a linear regression model) were combined with two prosthesis survival functions. The first was estimated from an study including primary KA from 1995 to 2000, and the second survival was estimated from the Catalan Registry of Arthroplasty, including primary KA from 2005 to 2013.

The simulation results were analysed in the short-term (2015) and the long-term (2030).

The results shows a variation in the number of revisions depended on both the primary utilisation rate and the survival function applied, ranging from increases of 8.3% to 31.6% in the short term, and from 38.3% to 176.9% in the long term. The prediction of increases in overall surgeries ranged from 0.1% to 22.3% in the short term and from 3.7% to 98.2% in the long term.

Projections of the burden of KA provided a quantitative basis for future policy decisions on the concentration of high-complexity procedures, the number of orthopaedic surgeons required to perform these procedures, and the resources needed.

Chapter 4

System modelling for improving operational performance and patient experience

Chapter 3 introduced the challenges faced by endoscopy services across the UK and presented the modelling of the NHS Bowel Cancer Screening Programme in England, as well as the analysis of activity, capacity and demand for endoscopy services across the healthcare economy of the Wessex region in southern England.

This chapter describes the application of system modelling for improving operational performance and patient experience through the reduction of patient's Length of Stay (LoS) in a gastrointestinal endoscopy unit in one of the Hospitals in Wessex.

This chapter is structured as follows: Section 4.1 introduces the problem and research aims; Section 4.2 presents the research methods and design; The intervention strategies and results are presented in Section 4.3; Section 4.4 focuses upon conclusions and study limitations; Finally, Section 4.5 summarises the chapter.

4.1 Introduction

Changes in demography and population health status, as well as new strategies to improve population health and new technology roll-out (such as the NHS bowel scope programme), have led to an increase in demand for endoscopic procedures across the UK. With the increase in demand, there is a greater need for achieving efficiency of endoscopic resources and to improve the patient experience within gastrointestinal endoscopy units.

This study applies system modelling and simulation to identify interventions within the patients and clinical staff flows that can help improve efficiency and patient experience in a gastrointestinal endoscopy unit of a large hospital. We focus on the identification of simple-to-implement changes to reduce the patient time in the endoscopy unit.

4.2 Methods and design

The study was conducted at the Frimley Park Hospital endoscopy unit, part of the Frimley Health NHS England Foundation Trust. The hospital provides acute services to a population of 400,000 people across North-East Hampshire, West Surrey and East Berkshire. The hospital employs almost 3,700 whole time equivalent staff and has around 750 beds. The Trust hosts a Ministry of Defence Hospital Unit with military medical, surgical and nursing workforce fully integrated into the NHS staff. The hospital was one of the only three hospitals in England rated *outstanding* by the Care Quality Commission in 2015.

The project was lead and managed by NHS England Wessex Clinical Network (CN) using the PRINCE2 methodology (Projects in Controlled Environments), A programme manager methodology used by the UK Government and the private sector [1]. The project was overseen by an interdisciplinary steering group which consisted of staff from the endoscopy unit, hospital managers, and members of the CN.

The endoscopy manager led the retrospective data collection. Staff interviews within the endoscopy unit, process mapping and time motion study, simulation ideation, development and data analysis were led by a researcher from the University of Southampton (UoS). Simulated results were first discussed and presented to the service manager; these presentations served to validate and demonstrate the reliability of the results of the simulation when different parameters were modified.

4.2.1 Endoscopy unit setup

The unit consists of: 5 endoscopy procedure rooms; 1 patient general waiting area; 3 pre-procedure rooms for male and 3 pre-procedure rooms for female patients (where patients are prepared for their procedure, i.e. placement of intravenous catheter (IV), pre-procedure paperwork completed and informed consent); 2 additional waiting areas as part of the pre-procedure zone (gender specific areas); 2 recovery rooms (gender specific areas) with 7 beds each; 1 waiting area or discharge lounge where patients wait for a discharge; and 1 discharge room. Administrative, storage and cleaning areas were excluded from the analysis.

The unit is open from 8am to 7pm Monday to Friday and provides a 24-hour emergency service; there are no weekend procedures performed except in cases of emergencies. 9 elective sessions per day are performed on a base of 12 endoscopy points each (unless training). One session per day is reserved for inpatient emergencies.

Patients arrival times are as follows: AM sessions: 8 am and 10 am, 6 points for each time; PM sessions: 1 pm and 3 pm, 6 points for each time. Consultants arrive at 9 am for morning list, and 2 pm for evening list.

The unit is staffed by a combination of full-time employees and variable number of per-diem staff: 1 endoscopist and 2 nurses per endoscopy room; 3-4 nurses in each of the 2 recovery areas; 2 nurses admitting and consenting patients; 3 preparation rooms in each area (for male and female) and 1 circulating nursing manager (present on the floor in the preparation and/or recovery area to oversee workflow and manage any issues that may arise during the course of the day).

The most common endoscopic procedures at Trust are investigations of the digestive system: Gastroscopy, Sigmoidoscopy, Colonoscopy, Percutaneous endoscopic gastroscopy (PEG), Endoscopic retrograde cholangiopancreatography (ERCP). In addition to the gastroenterological endoscopies, the unit also offer Bronchoscopy and Cystoscopy.

4.2.2 Process mapping and time motion study

Scope. A time motion study was conducted for a period of a month by an industrial engineer. The engineer shadowed the nurses and patients for each step of the endoscopy process. The scope is limited to observing the activities within the gastrointestinal endoscopy department, starting when the patient arrives at the department, and ending when the patient leaves the unit. Figure 4.1 highlight the project scope.

The endoscopy department is targeted for the study due to its critically impact on the colorectal cancer waiting times, a priority for NHS in Wessex as highlighted in the 'Wessex Strategic Vision for Cancer' report [155].

Data Collection. Prospective and retrospective data were used in the project.

Three datasets were extracted from the hospital IT system, and anonymised by staff from the hospital. The first dataset contains the activity performed at the endoscopy unit between September 2014 and August 2015, including a record of

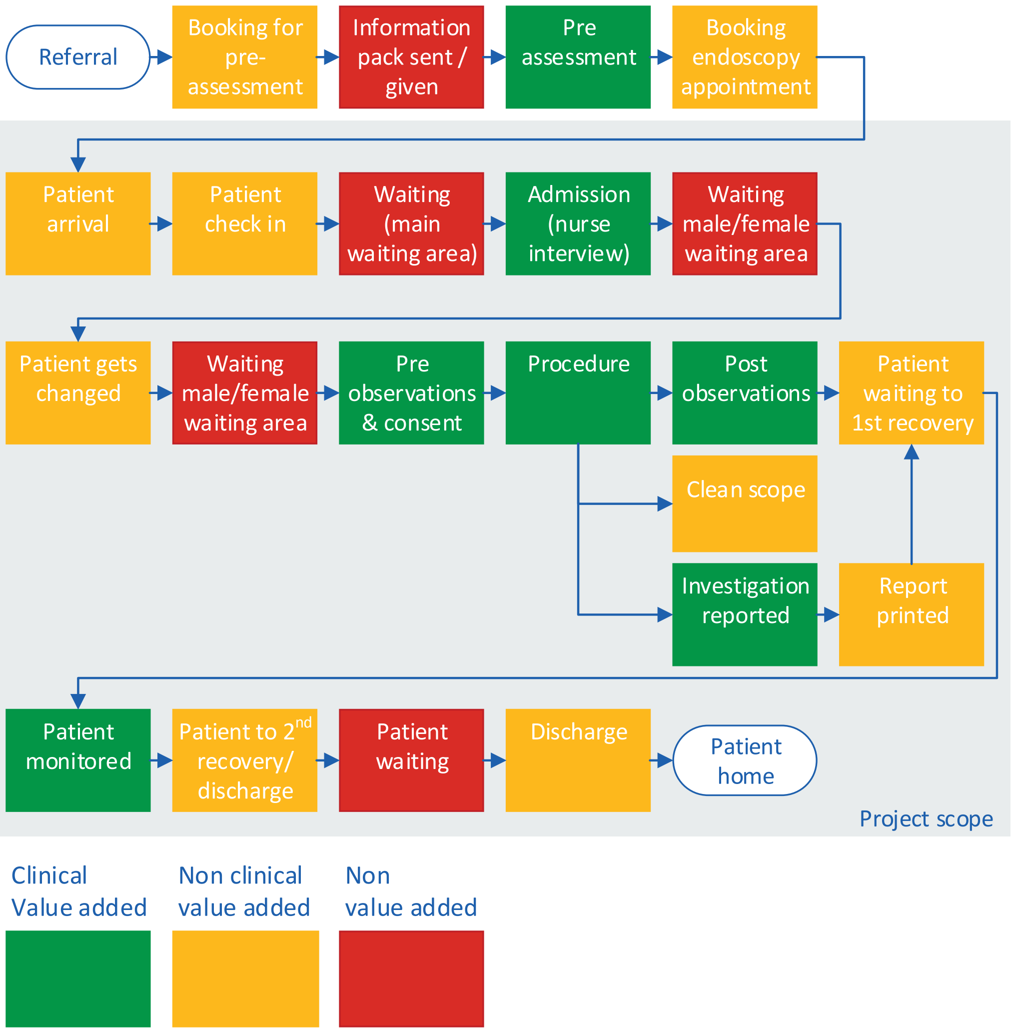

Figure 4.1: Process map for endoscopy department. Grey area represents the project scope. A colour coding was used to represent the value added of the different activities part of the process.

patient arrival and discharge times. The second dataset summarise the procedures not carried out on the endoscopy unit in the same period of time. The last dataset includes the cancelled procedures on the endoscopy unit. Table 4.1 summarises the datasets.

More detailed process times should be available from a paper form called *Endoscopy Unit Day Care Plan* (EUDCP) implemented in January 2015, to collect - among other information - a record of patient arrival time, time of admission, procedure start/finish time, and discharge time. In a review of the EUDCP, it was observed the data lacks completion of all the times.

The time motion study enables sequential process mapping of the steps and measurement of each task's time estimation, which is crucial for system modelling and simulation. The research team carries out the time motion study of the process using a mix methodology, including time keeping, clinician and nurse estimations, paper-based data collection, and literature review, due to the tight deadline to deliver the project.

A process flow was constructed based on information provided by hospital managers and revised with staff of the endoscopy department. A colour code was added. A cross functional flowchart was developed based on information provided by staff from the gastrointestinal endoscopy department, to represent in detail the different tasks and staff involved in each activity. Differences were noticed between the actual steps and the steps that the member of the staff described, as well as minor practice variance among nurses and endoscopists. For this study, the process steps that most staff members actually take are adopted and analysed. Figure 4.1 shows the process map for the endoscopy department. Figure 4.2 shows the cross functional flowchart.

Endoscopy unit workflow. Patient arrive and 'check in' with a receptionist in the front lobby before being sent to the main waiting area where a nurse is informed of their arrival. The patient information is recorded onto the hospital Electronic Patient Record system, and the date and arrival time is registered manually on the paper-based *Endoscopy Unit Day Care Plan* (EUDCP) attached to each paper-based patient record.

An admission nurse calls the patient through to the admission room to complete necessary paperwork, including patient *Pre-Admission Medical History* (PAMH), allergies, preparation, medication list, and sedation preference. The nurse will describe the procedure and discharge process to the patient, obtain the patient signatures for the care plan and an arm band is placed on the patient. The admission time is recorded manually on the care plan by the nurse and the patient record and care plan is put in the surgery queue repository (outside the procedure rooms). The patient then returns to the waiting area until a nurse takes him/her to the preparation room where they may ask the patient to change. The endoscopist will then call the patient to the preparation room to check the pre-admission documentation, describe the procedure and associated risks and obtain the patient *informed consent.* The patient returns to the preparation-waiting area. From here, patients are transported to the procedure room by a procedure nurse.

Table 4.1: Summary of datasets used to populate the endoscopy department simulation model.

Data source	Attribute information
Endoscopy unit activity dataset: Procedures carried on the endoscopy unit between Sept 2014 and Aug 2015 (13391 instances)	1. AdmitWard: Admission ward 2. AgeStartEpi: Patient age at start episode 3. OPCS4Code: OPCS Classification of interventions and procedures version 4 (OPCS-4) 4. OPCS4Code3Description: OPCS-4 code description (third character) 5. OPCS4Code4Description: OPCS-4 code description (fourth character) 6. CESpeciality: Speciality (Ent, Ger, Med, Orth, Surg, Thme, Ur) 7. WLCode: Waiting list code 8. IPWaitDays: Inpatient waiting time (days) 9. MonthOfEnd: Procedure date 10. AdmitDate: Patient admission date and time 11. DischDate: Patient discharge date and time 12. ActPatClass: Patient class (day case, elective, emergency) 13. MethAdm: Admission method 14. CodeDesc: Description of the admission method (Accident and Emergency, Booked with date, Immediate other, Planned series, Waiting list) 15. CodeLink: Admission method ID
Non-endoscopy activity dataset: Summary of procedures not carried out on the endoscopy unit between Sept 2014 and Aug 2015 (345 instances)	1. AdmitWard: Admission ward 2. OPCS4Code: OPCS Classification of interventions and procedures version 4 (OPCS-4) 3. OPCS4Code3Description: OPCS-4 code description (third character) 4. OPCS4Code4Description: OPCS-4 code description (fourth character) 5. Daycase: Number of day cases not carried out on the Endoscopy Unit 6. Elect: Number of elective cases not carried out on the Endoscopy Unit 7. Emerg: Number of emergency cases not carried out on the Endoscopy Unit
Cancelled Operations dataset: Cancelled operations on endoscopy ward between Sept 2014 and Aug 2015 (438 instances)	1. OpCancReason: Reason for cancellation (Hospital cancelled, Patient decision, Patient unfit) 2. OperationText1: Procedure description (free text) 3. AdmitDate: Patient admission date and time 4. DischDate: Patient discharge data and time 5. AdmissionReason: free text 6. ExpWard: Ward (endoscopy) 7. WlDiagGroup: Waiting list diagnostic group (Bowel, Bronch, Chcol, Chcyst, Child, Chogd, Colon, Days, Endo, Endos, FleSig, Flex, Flexy, Gen, Med, Misc, Ogd, Rectal, Respir, Sigmo, Twr, Urol)

Once the patient is in the endoscopy room, the procedure staff would typically consist of the endoscopist, 2 procedure nurses, and an anaesthesiologist if Monitored Anaesthesia Care or General Anaesthesia is required.

The endoscopist performs the procedure and, once the endoscope has been removed, will generate the electronic endoscopy report at a computer workstation located at the same room.

After the procedure, the endoscopy nurse transports the patient to the post-procedure recovery room (or to discharge lobby if patient is not sedated). Room turnover is initiated as soon the procedure finishes for the second endoscopy nurse.

When recovered, the patient is moved to a third waiting room (discharge lobby), where tea and biscuits are available. The patient is then called to the discharge room where a discharge nurse (or endoscopist, if required) informs the patient of the results or the procedure and discharges him/her.

Data analysis. The collected information was evaluated for outliers and their impact on estimating the service distribution function was analysed. From September 2014 to August 2015, 13226 diagnostic procedures were analysed. As seen in Figure 4.3, the mean number of patients per day was 46 (SD 12.7), showing a large variation in points allocation over different days within the time period. Another key point is related with patient LoS; 40% of the day case patients spent 4 or more hours at the Endoscopy unit. In terms of LoS, 60% of the day case patients has a LoS $>$ 3 hours, 40% of them expended 4 or more hours at the unit. The scheduling system used at the unit are also observed from the dataset, with a high frequency of patients been admitted at 8am, 10am, 1pm, and 3pm. High proportion of the discharges are performed at the end of the morning list.

The Figure 4.4 presents a Sankey Diagram with information extracted from the *Endoscopy unit activity dataset*, where 99% of the records are related with Day cases. The main three specialties are Surgery (48%), Medicine (33%), and Urology (17%). 79% of the cases are *Waiting List* admissions, 14% are *Planned Series*, and 7% are *Booked* admissions. An analysis of the OPCS-4 (OPCS Classification of Interventions and Procedures version 4) codes shows that the activity can be divided as follows: 32% for Diagnostic fibreoptic endoscopic examination of upper gastrointestinal tract, 18% for Diagnostic endoscopic examination of colon, 14% for Diagnostic endoscopic examination of lower bowel using fibreoptic sigmoidoscope, 10% for Endoscopic extirpation of lesion of colon, and 12% for other interventions. 45% of the activity is related with the Lower Digestive System, 34% with the Upper Digestive System, and 15% with the Urinary System.

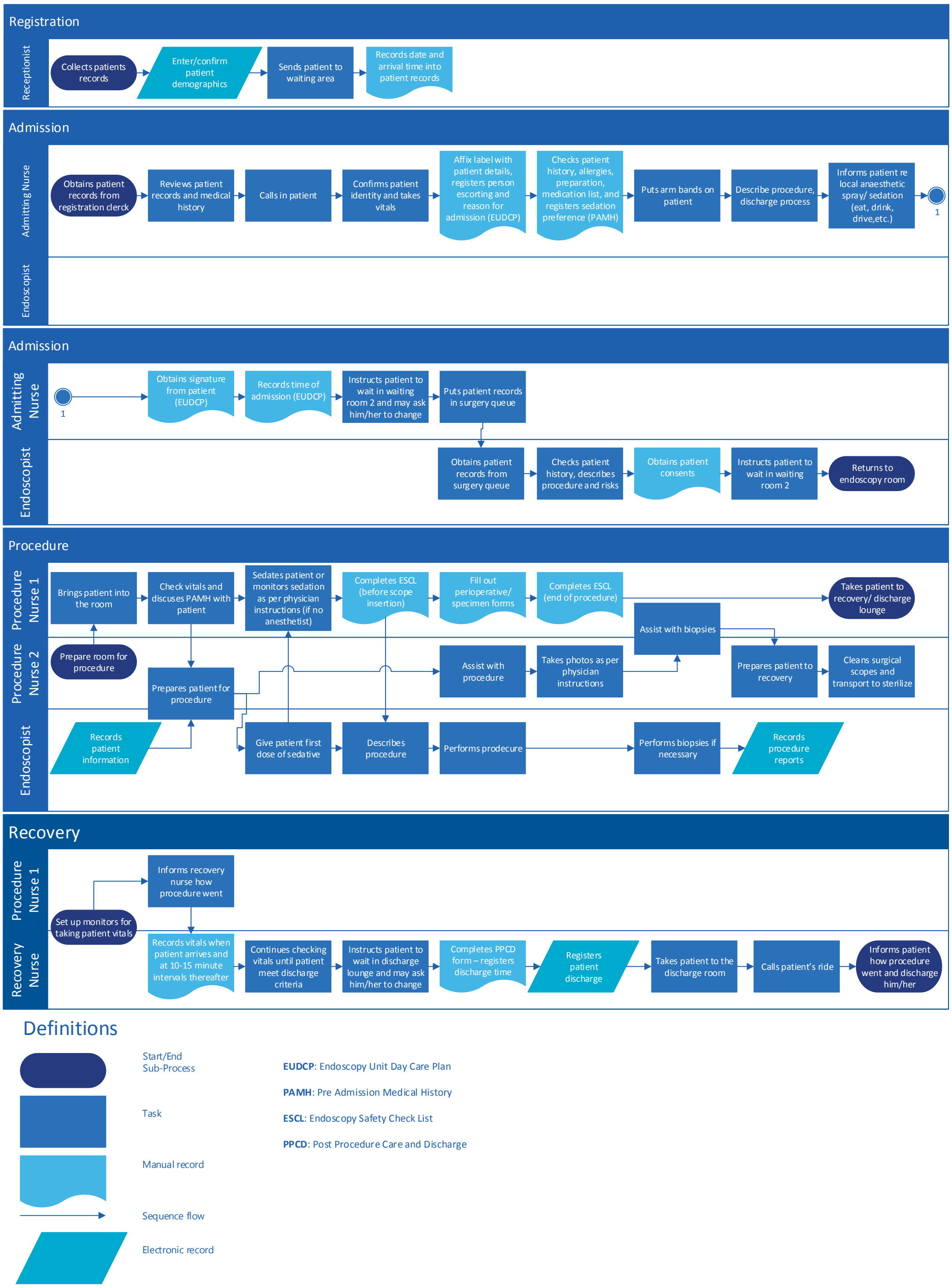

Figure 4.2: Cross functional flowchart for endoscopy department. Includes main subprocess: registration, admission, procedure and recovery.

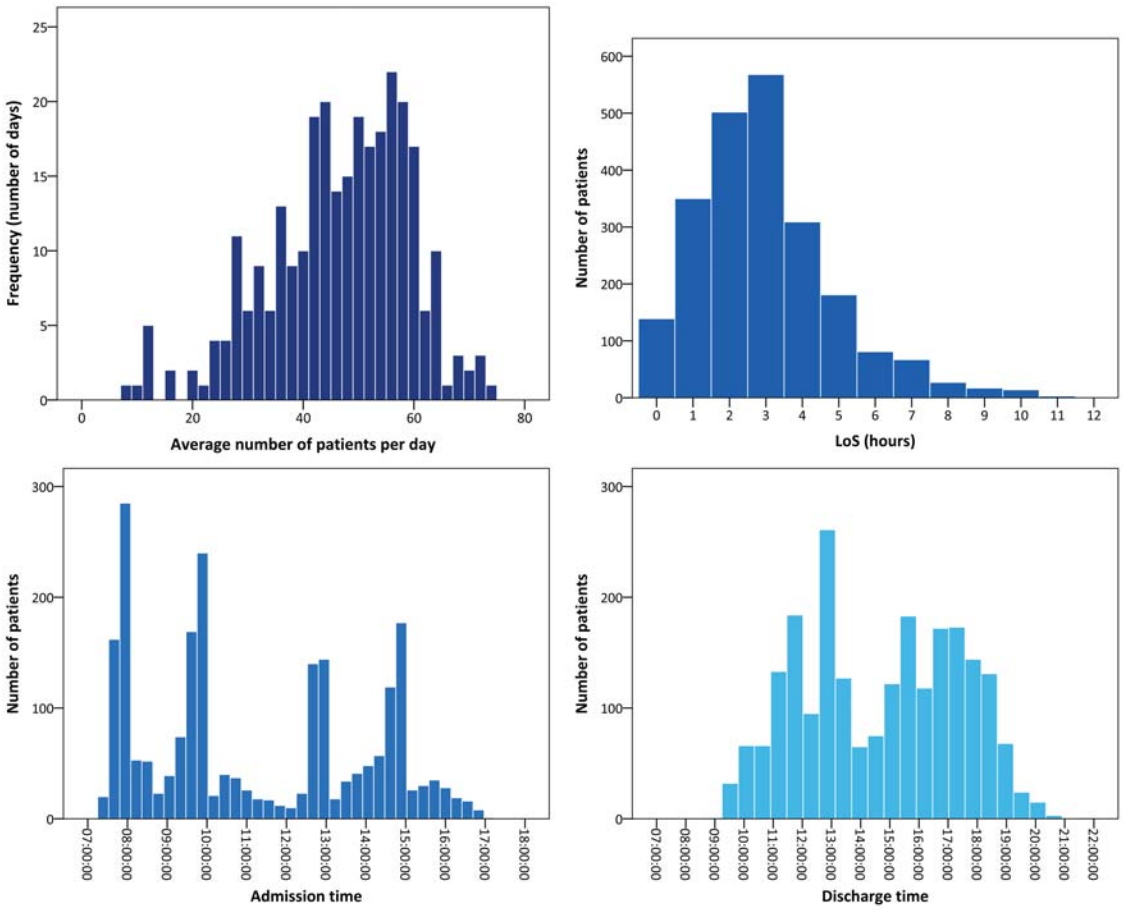

Figure 4.3: Endoscopy procedures between September 2014 and August 2015. The findings visualised above show: number of patients per day, patient length of stay (LoS) in hours at the endoscopy unit, admission time, and discharge time. These results are part of the data used as inputs into the simulation model.

As mentioned above, the unit implemented in January 2015 a paper form called *Endoscopy Unit Day Care Plan* (EUDCP), including demographic and clinical information, as well as a record of times related with the patient flows, including patient arrival time, admission time, procedure star and end, and patient's discharge time.

The Figure 4.5 shows the process times estimated using the EUDCP information collected with the EUDCP forms, details as follows: Arrive to admission is the time between the patient check-in and the end of the admission process with the nurse, Admission to procedure start includes the time between the end of the admission process and the time when the endoscopy procedure begin at the procedure room, Procedure time is also recorded, and finally, the time between end of procedure and patient discharge is also recorded. Figure 4.6 shows the Length of Stay (LoS) and the

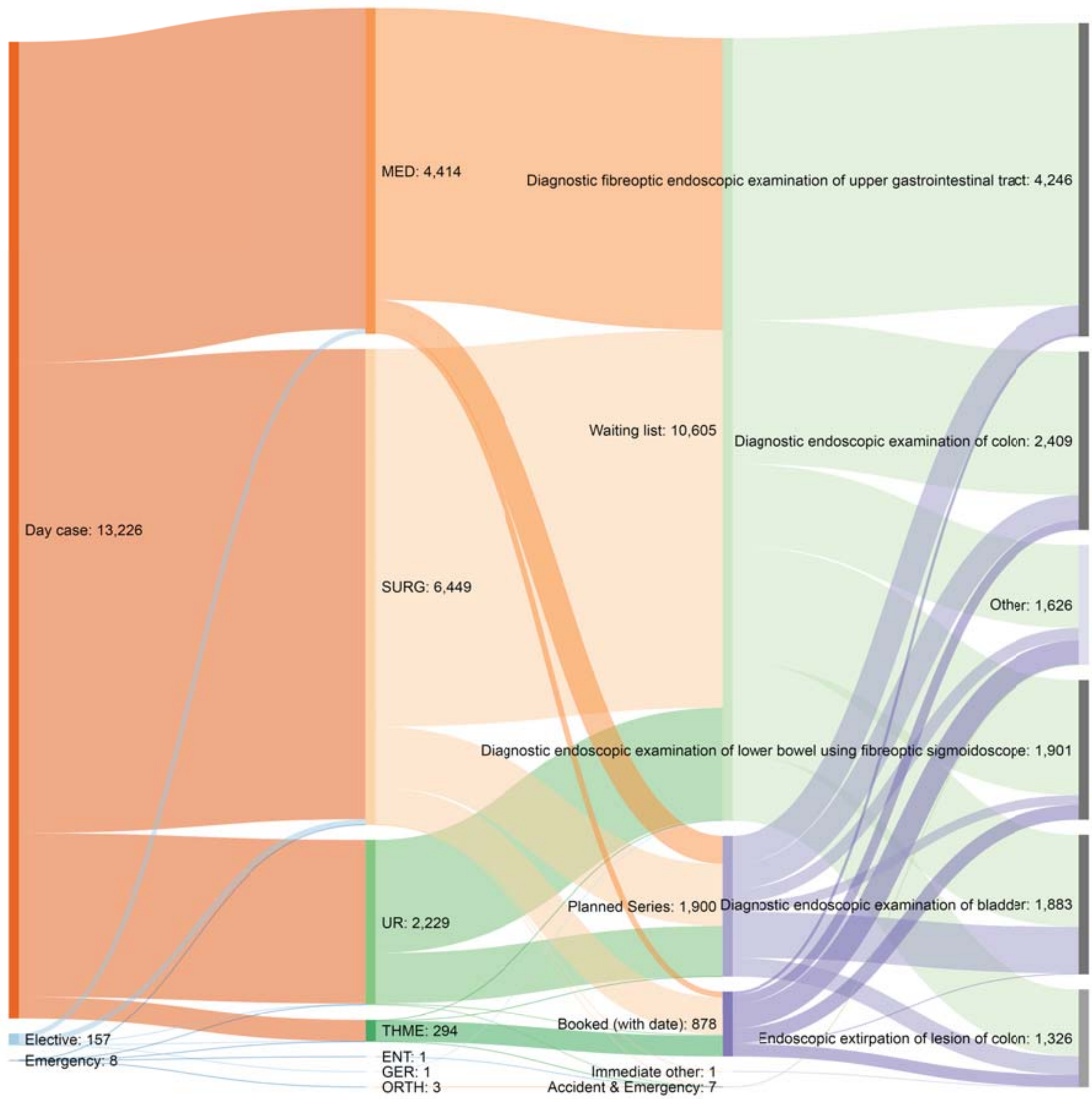

Figure 4.4: Sankey Diagram with endoscopy procedures performed between September 2014 and August 2015. The diagram shows the relations between type of patients, specialties, type of admission, and the interventions and procedures, using the OPCS-4 (OPCS Classification of Interventions and Procedures version 4).

times describes above for a randomly selected cohort of 27 patients.

Figure 4.7 shows detailed times for four patients, the first example represents a sedated gastroscopy and colonoscopy, the patient arrived at 14:55h and was discharged at 18:00h, 14% of the time was expended between arrival and end of the admission task, 32% of the time was waiting time between admission and the start of the procedure, 22% of the time was related with the endoscopy procedures, and 32%

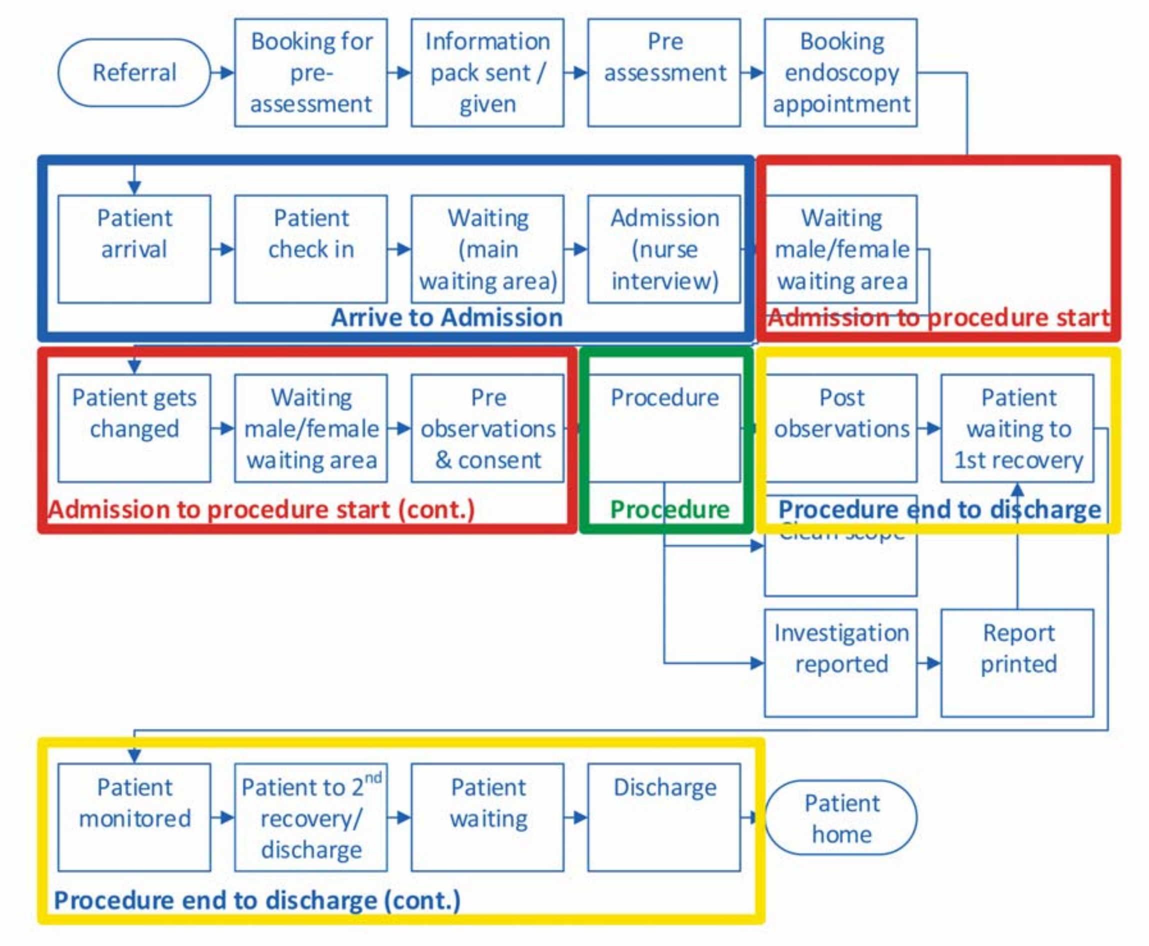

Figure 4.5: Process map for endoscopy department. Colour represents the times estimated using the EUDCP (Endoscopy Unit Day Care Plan) form.

of the time was between the end of the procedure and discharge. The second case is a non-sedated gastroscopy, with 40% of the time between admission and the start of the procedure, and 9% dedicated to the endoscopy procedure. The third case is a sedated bronchoscopy, where the patient dedicated 72% to wait before the procedure, and 9% corresponded to procedure time. The final example is a sedated gastroscopy, with 45% of the time waiting before the procedure and 3% dedicated to the gastroscopy procedure.

Long waits were observed between the end of the admission process and the start of the endoscopy procedure. As described at the Figure 4.1, in this step all the activities are classified as *Non Clinical Value added* or *Non Value added*, as can be described as a patient waiting to be called to start the procedure.

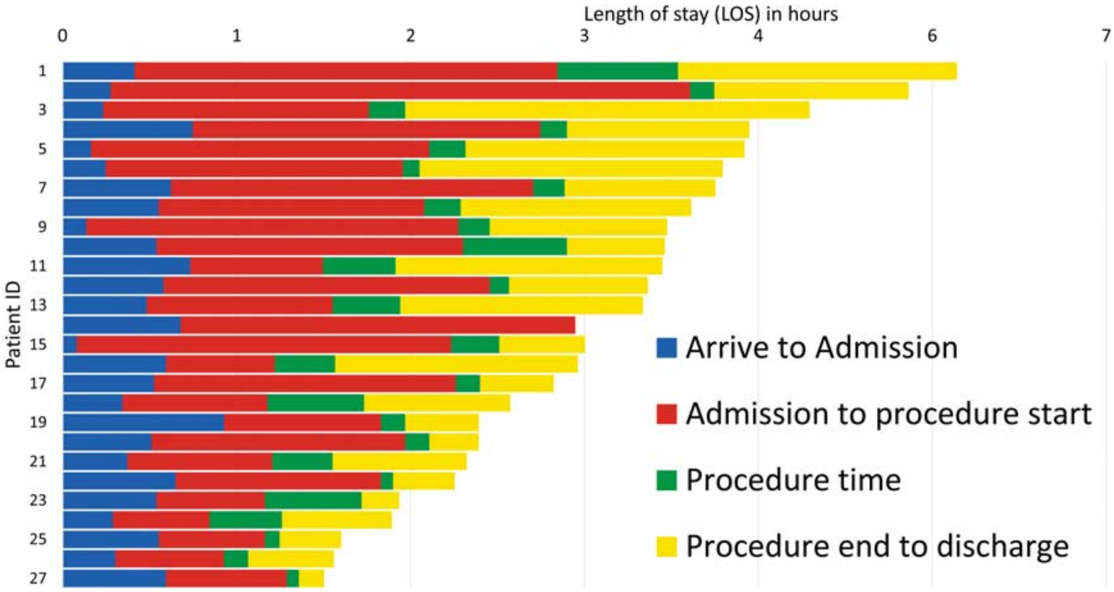

Figure 4.6: Endoscopy unit Length of Stay (LoS) and times between arrival and admission, admission and procedure start, procedure time, and procedure end and discharge of a retrospective randomly selected cohort of patients.

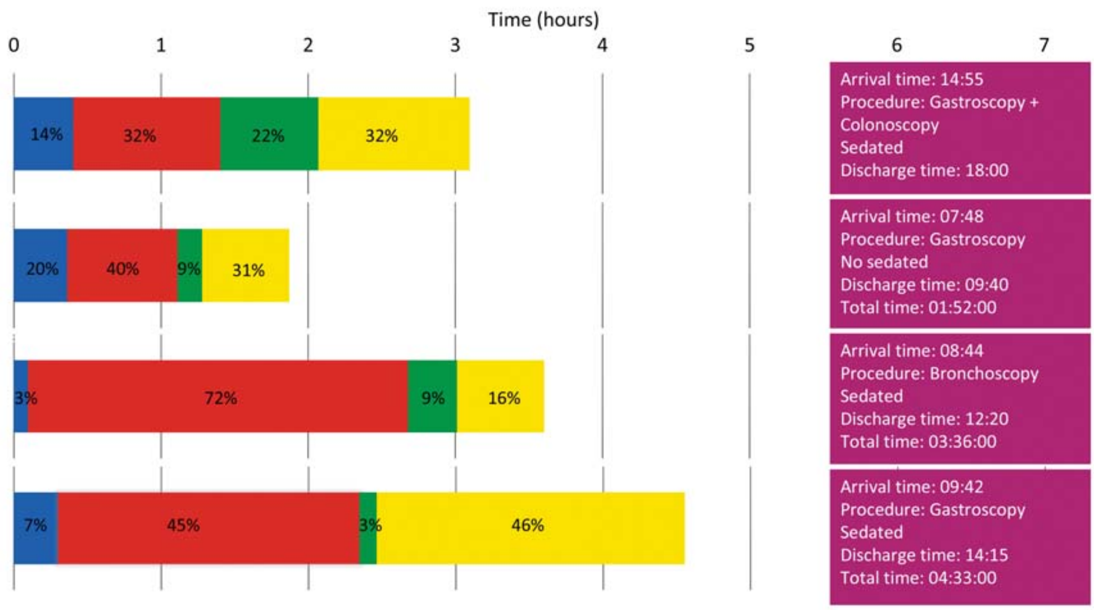

Figure 4.7: Process times for four randomly selected patients.

This justifies our focus on patient experience: the number revealed that there could be substantial opportunities for improvement and delays reduction. The individual tasks that comprises the endoscopy procedure process are excluded of this analysis because one the aims is to improve the process to free time for the staff to be in contact with the patient and to perform the activities defined as *Clinical Value Added*.

Analysis of the *Cancelled Operations dataset* shows 438 cancellations on the endoscopy unit between September 214 and August 2015, equivalent to 3.1% of the procedures performed in the same period of time. 119 of the cancellation are recorded as hospital cancellations, 80 are related with patient decision, and 239 are described as patient unfit for the procedure.

4.2.3 Simulation model

A Discrete Event Simulation (DES) model (see 2.3) comprising all steps in the endoscopy process was developed using the software Simul8 (SIMUL8 Corporation). The model was based on the process mapping and data described in the Section 4.2.2. The input data consist of three components:

- Service demand, including records for arrivals, cancellations, patient demographics, endoscopy case mix.
- Process time distributions, estimated from the time motion study data.
- Resources and patient journeys through the service, estimated from the time motion study and information provided by the endoscopy manager.

The objective of the simulation model is to analyse potential improvements in the current operation of the endoscopy unit, and to measure the impact of operational changes to improve throughput balancing resource use and reducing the patient Length of Stay (LoS) at the unit. The computer simulation approach also allows the hospital teams to visualise departmental processes and interactions before any significant system changes.

Figure 4.8 shows the Simul8 components (work items, entrance, activities, queues, exit and resources) and movement route of patients (entities) and staff (resources) added into a simplified version of the layout developed as part of this project. Simulation properties, such as process time distributions, patient demographics, endoscopy procedure case mix, staff working hours, patient appointment systems, endoscopy sessional allocation, cancellations, etc., were added to the model so that various 'what if' scenarios could be analysed.

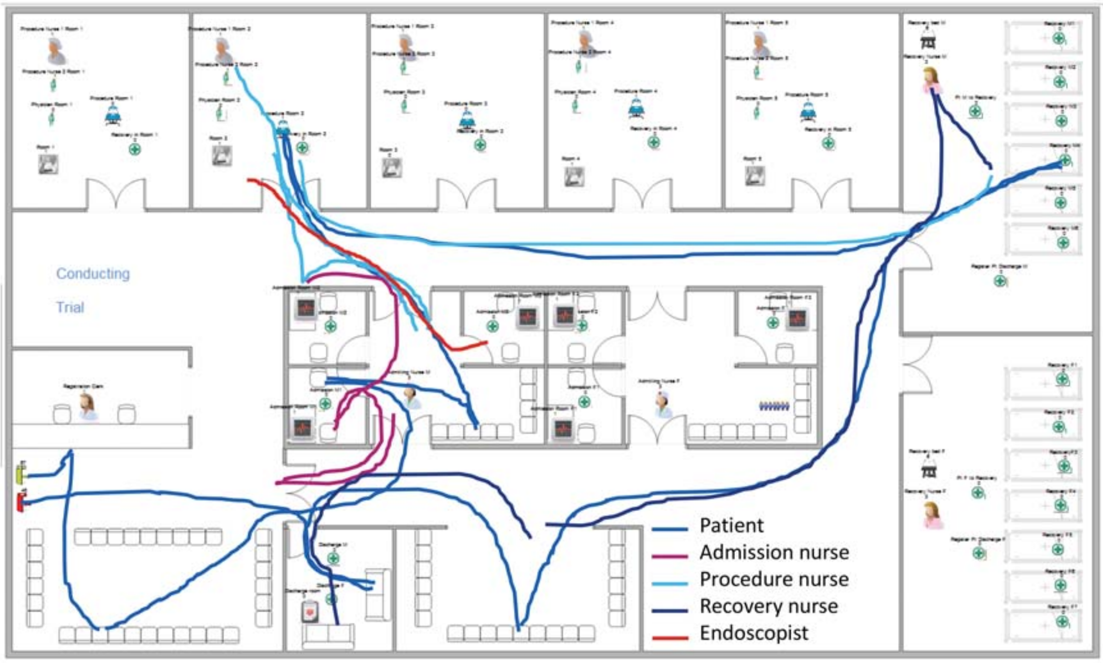

Figure 4.8: Endoscopy layout plan, Simul8 components, and movement route of patients and staff.

Baseline model. The baseline simulation model was developed using the assumptions listed as follows: No late-cancellations were assumed in the model, as well as no contingency points for training lists. The point system used currently at the unit was used to weight the procedures and to schedule the capacity, e.g. 2.2 endoscopy points for colonoscopy and 1.1 for and OGD, means that more points than JAG recommendations are assigned (JAG recommends 2 points for a colonoscopy, and 1 point for an OGD procedure).

Using information from the endoscopy unit, an average of 60 patients appointed per day was simulated. Master timetable (endoscopy sessional allocation) provided by the endoscopy manager was used, including 5 rooms, 9 elective sessions per day, 12 points each session. One session per day is reserved for inpatient emergency (JAG recommendation is 1-2 points per list for emergencies). No ward rounds into analysis.

Workforce sessional allocation, including staff availability modelled using information provided by endoscopy manager, as described as follows: 2 nurses per endoscopy procedure room, with the first nurse responsible for calling patient from admission and transporting them to recovery after procedure. 3-4 nurses in each recovery room. 3 nurses admitting patients.

Table 4.2: Validation of simulated patient Length of Stay against 1 year of Electronic Patient Records, and an independent data collection.

	Los Mean (minutes)	95% CI
Simulation model	202	188 - 216
Electronic Patients Records (EPR)	225	223 - 227
Paper-based records	222	-
Error estimated with EPR	10%	-
Error estimated with paper-based records	9%	-

5 endoscopy rooms and 3 preparation rooms, fully equipped and always available are assumed.

The simulated patient arrival time is based on the current protocol used in the unit. For morning sessions, the patients are booked at 8 am and 10 am, with a maximum of 6 points each time. For evening sessions, the patients are booked at 1 pm and 3 pm, with a maximum of 6 points each time. Consultant arrive 9 am for morning lists, and 2 pm for afternoon list, by which time patients are already admitted by a nurse.

4.2.4 Model validation

The output from each simulation model consists of several metrics, including dairy room and staff utilisation rate, and patient Length of Stay at the unit. After the patients and staff flows were simulated, and the parameters were estimated, we tested the baseline model against the hospital patient records, and an independent set of patients time in endoscopy collected by one of the nurses during two days. The estimated error of the simulation model against the Electronic Patient Records (EPR) is 10%, and 9% when compared with the independent data collection.

Figure 4.9 shows the results of the simulation using the baseline model, patient LoS distribution is presented against 1 year of EPR, and the Figure 4.10 presents the simulated patient LoS distribution against an independent data collection. Figure 4.10 also includes a comparative between the time between patient arrival and end of the admission, between the time of admission and endoscopy procedure start, procedure time, and the time between procedure end and patient discharge.

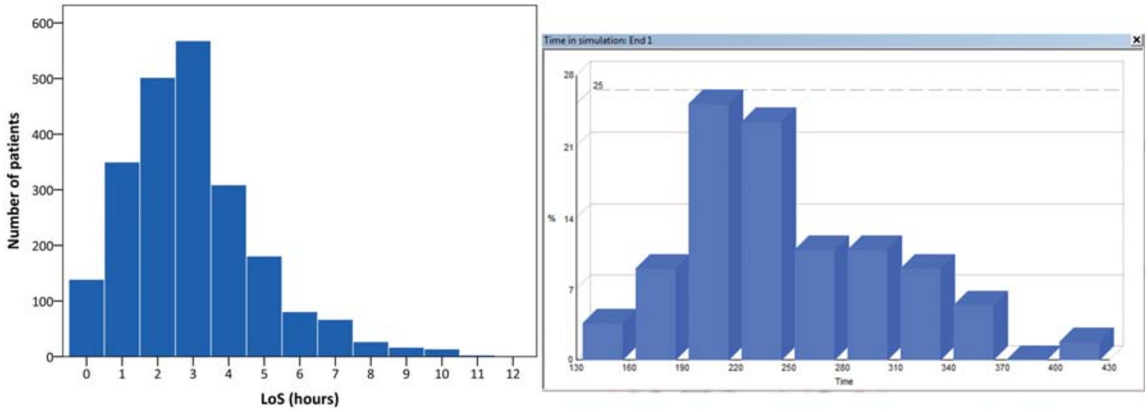

Figure 4.9: Validation of simulated patient Length of Stay distribution against 1 year of Electronic Patient Records.

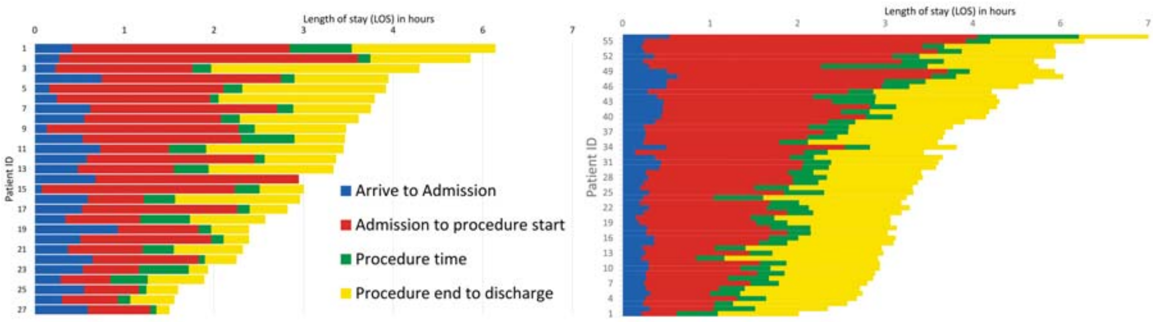

Figure 4.10: Validation of simulated patient Length of Stay distribution, and different process times against an independent data collection.

4.3 Intervention strategies and results

4.3.1 Baseline model

Once the baseline model was validated by the clinicians, nurses and managers involved in the project, the simulation model was used to evaluate the Endoscopy rooms occupancy rate. Figure 4.11 shows the results for the five endoscopy rooms and for the whole endoscopy unit. Endoscopy points were used to estimate the occupancy rate.

Assuming that one session per day is reserved for inpatient emergencies (Endoscopy room 3), the average occupancy rate for the whole endoscopy unit (including the five endoscopy rooms) is 73.2% in the morning sessions, and 70.8% in the after-

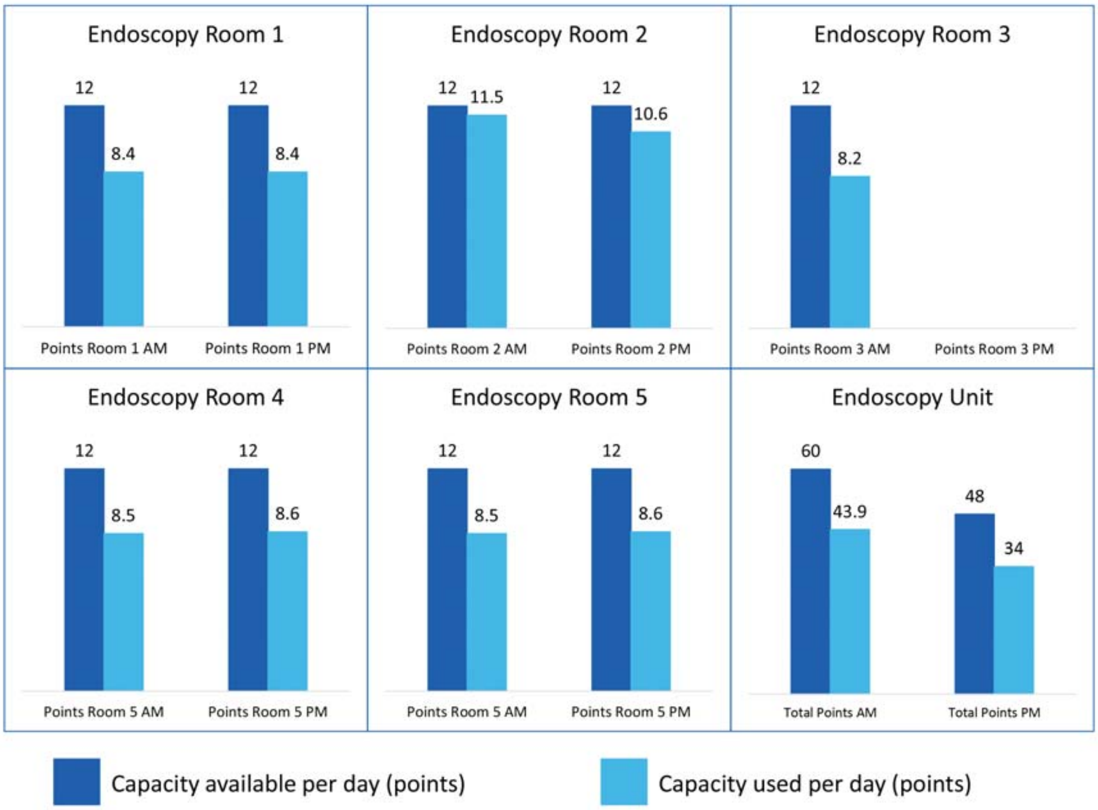

Figure 4.11: Diary endoscopy room occupancy.

noon sessions. If we estimate the occupancy rate for the afternoon sessions with a capacity of 12 points for the five endoscopy rooms (meaning no points are reserved for inpatient emergencies), the rate for the afternoon session is 56.7%.

4.3.2 Strategies and potential improvement

On completion of the validation of the baseline model, it was used to evaluate new scenarios. Scenarios for the model were developed based on follows key sources:

1. Input and observation from staff members of the endoscopy unit.
2. Observations from the team who conducted the study and built the DES model.
3. Changes to endoscopy unit structure or processes that in the medical literature have been shown to improve efficiency.

Only modifiable factors *with no extra investments* (such as scheduling and staff) were considered given that facility factors (e.g. number of rooms) were decided to

Table 4.3: Summary of factors and scenarios analysed.

Factors studied	Scenarios
Appointment time	(S1) Baseline. (S2) 60-min: 9-10am, 2-3pm appointments. (S3) 60-min: 8-9-10am, 1-2-3pm appointments. (S4) 60-min: 9-10-11am, 1-2-3pm appointments. (S5) 30-min: 9-9.30-...-11.30am, 1.30-2-...-4pm appointments.
Admission time	Baseline. (S6) Admission times mean: 2, 5, 10 or 20 minutes.
Endoscopy procedure time	Baseline. (S7) Endoscopy procedure times mean: 10, 30 or 50 minutes.
Recovery time	Baseline. Recovery times mean: 15 minutes. Recovery times mean: 30 minutes. Recovery times mean: 45 minutes.
Endoscopists working hours	Baseline. Endoscopists available between 8am to 3pm. Endoscopists available between 8am to 4pm. Endoscopists available between 8am to 5pm. Endoscopists available between 8am to 7pm.
Endoscopy room turnover time	Baseline. Room turnover time means: 5, 10, 20, 40 or 60 minutes.

be fixed by the project steering group. The assumption of nothing changes except factor, or factors, being studied was used in this work. Table 4.3 includes a summary of the factors and scenarios studied.

All the parameters and distributions were based on historical data, and SPSS (IBM SPSS Statistics 21.0) was used to develop Statistical distributions that matched historical data with a high degree of confidence.

Appointment time (patient arrival time). The first factor analysed is the endoscopy appointment schedule. In the baseline model, patients were booked at 8am and 10am for the morning sessions, and 1pm and 3pm for the afternoon sessions. 4 new scenarios were generated:

- (S1), patient appointments at 9am and 10am for morning sessions, 2pm and 3pm for afternoon sessions.

- (S2), patient appointments at 8am, 9am, and 10am for morning sessions, 1pm, 2pm, and 3pm for afternoon sessions.

- (S3), patient appointments at 9am, 10am, and 11am for morning sessions, 1pm, 2pm, and 3pm for afternoon sessions.
- (S4), patient appointments every 30 minutes, between 9am and 11.30am for morning sessions, and between 1.30pm and 4pm for afternoon sessions.

Recovery time. The second factor studied is patient recovery time, modified implementing different pathways for sedated and non-sedated patients, with different sedation techniques, or new technology (for example, a carbon dioxide insufflator, that could help to speed up the recovery time and post-procedural pain reduction). The baseline model was developed with an average recovery time of 40 minutes and we created three new scenarios with different mean recovery times:

- (S5), 15-minutes recovery.
- (S6), 30-minutes recovery.
- (S7), 45-minutes recovery.

We also developed three new scenarios, analysing together the impact of recovery time and endoscopy appointment schedule, with appointments system based on the scenario (S4) (30-min: 9-9.30-...-11.30am, 1.30-2-...-4pm appointments):

- (S8), 15-minutes recovery, and patient appointments every 30 minutes, between 9 am and 11.30 am for morning sessions, and between 1.30 pm and 4 pm for evening sessions.
- (S9), 30-minutes recovery, and patient appointments every 30 minutes, between 9 am and 11.30 am for morning sessions, and between 1.30 pm and 4 pm for evening sessions.
- (S10), 45-minutes recovery, and patient appointments every 30 minutes, between 9 am and 11.30 am for morning sessions, and between 1.30 pm and 4 pm for evening sessions.

New working practices. Another factor analysed was the availability of physicians in the endoscopy unit. In the baseline model, the physicians were available between 9 h and 13 h, and between 14 h and 18 h, with a break for lunch between 13 h and 14 h. The new scenarios are based on different physician working hours and the assumption of 9 elective sessions per day, 12 endoscopy points each session, and one session per day reserved for inpatients emergencies:

- (S11), physician available between 8 am and 3 pm.
- (S12), physician available between 8 am and 4 pm.
- (S13), physician available between 8 am and 5 pm.

The scenarios described above do not assume that the same physician will be working all day with no breaks, but at least one physician will be available for each room during this hours (could be two or more physicians working part of the shift).

A new scenario (S14) was simulated, evaluating the impact of physicians available between 8 am to 7 pm, and 10 elective sessions per day, 12 endoscopy points per session, and no reserved sessions for inpatients emergencies. It is important to note that we used points to represent the capacity in the system, but the maximum patient number was constrained to 61 per day, based on historical data and endoscopy manager recommendations.

Endoscopy procedure time. The impact of the endoscopy procedure time was also analysed, assuming the same average procedure time for all the patients in the five endoscopy rooms, with three different times:

- (S15-1), 10-minutes average procedure time.
- (S15-2), 30-minutes average procedure time.
- (S15-3), 50-minutes average procedure time.

A set of 250 simulations, with 10 replications each, with every possible combination of procedure time across the rooms (10-min, 30-min, and 50-min) were also generated. Figure 4.12 shows the results of the simulations, average patient LoS, high and lower 95% range are included.

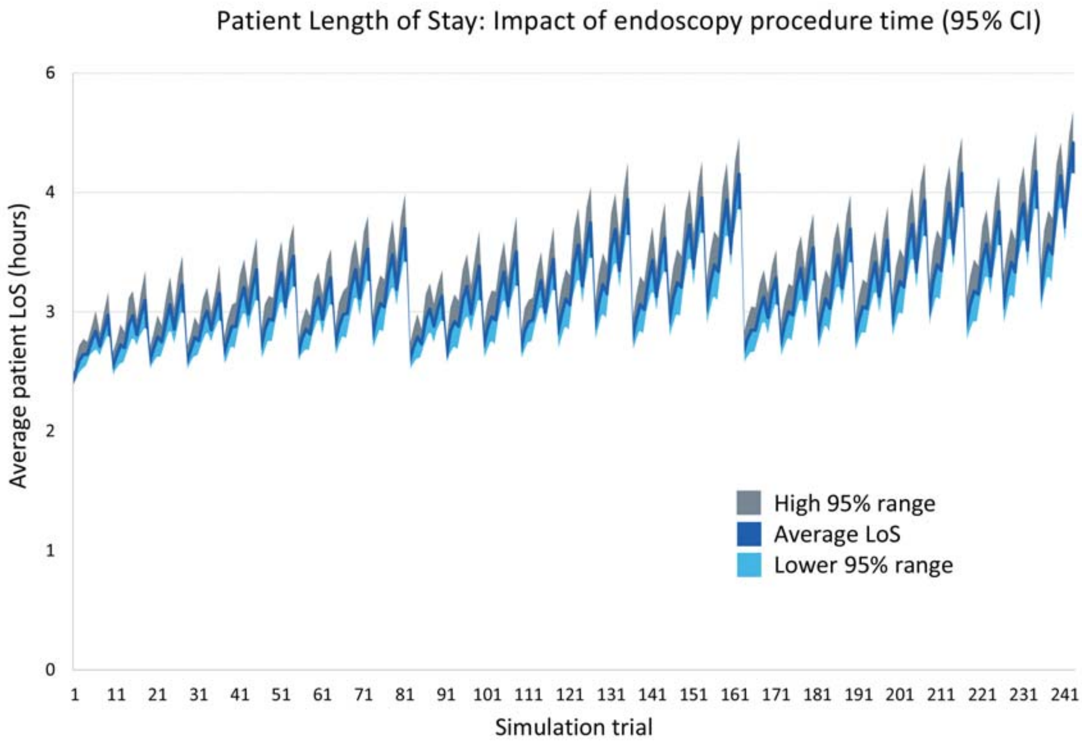

Figure 4.12: Summary of results. Impact of endoscopy procedure time (95% CI). Each point represents the average patient LoS for each of the 250 scenarios developed with all the combinations of 10-minutes, 30-minutes, and 50-minutes dedicated to endoscopy procedures in the five endoscopy rooms. 10 replications were executed for each simulation. 95% CI presented for each simulation.

Pre-procedural admission time (nurse interview). Other factor analysed is the impact of pre-procedural admission time of outpatients. Four scenarios were simulated, with the same average admission time for all the patients across the six admission rooms (3 for male, and 3 for female patients):

- (S16-1), 2-minutes admission interview.
- (S16-2), 5-minutes admission interview.
- (S16-3), 10-minutes admission interview.
- (S16-4), 20-minutes admission interview.

As in the previous analysis of impact of the procedure time, different scenarios were simulated with every possible combination of admission time across the 6

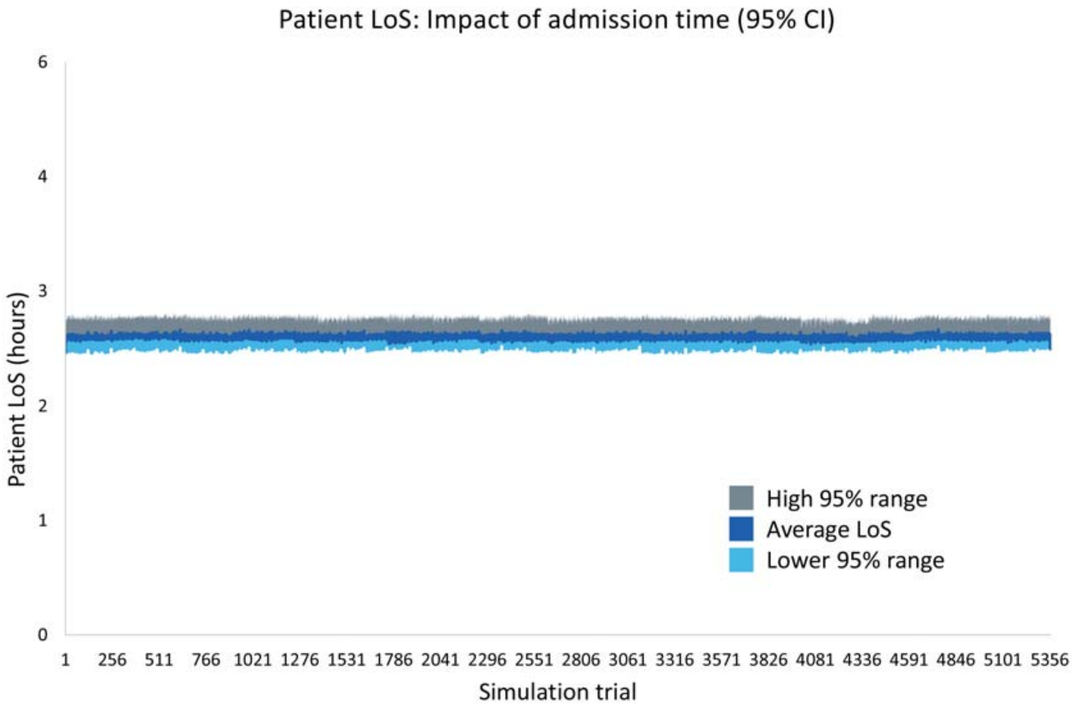

Figure 4.13: Summary of results. Impact of admission time (95% CI). Each point represents the average patient LoS for each scenario developed with all the combinations of 2, 5, 10, and 20-minutes dedicated to the admission process in each of the 6 admission rooms. 10 replications were executed for each simulation. 95% CI presented for each simulation.

rooms. Results of the simulations are presented at the Figure 4.13. No impact of the admission time in the patient LoS is observed.

Endoscopy room turnover time. Five new scenarios were simulated, evaluating the impact of endoscopy room turnover time. The same turnover time across the 5 endoscopy rooms was assumed:

- (S17-1), 5-minutes room turnover.
- (S17-2), 10-minutes room turnover.
- (S17-3), 20-minutes room turnover.
- (S17-4), 40-minutes room turnover.
- (S17-5), 60-minutes room turnover.

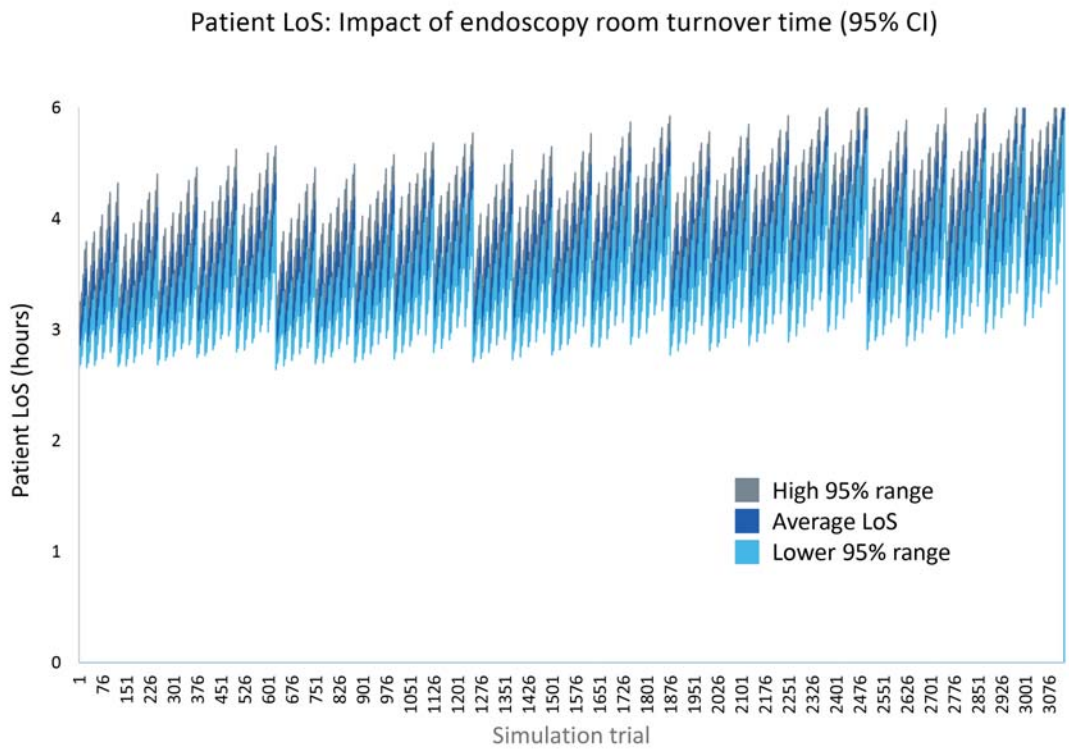

Figure 4.14: Summary of results. Impact of endoscopy room turnover time (95% CI). Each point represents the average patient LoS for each scenario developed with all the combinations of 5, 10, 20, 40, and 60-minutes dedicated to the room turnover in each of the 5 endoscopy procedure rooms. 10 replications were executed for each simulation. 95% CI presented for each simulation.

(S17-1) 5 min, (S17-2) 10 min, (S17-3) 20 min, (S17-4) 40 min, (S17-5) 60 min (as well as scenarios with every possible combination of turnover time across the rooms).

As in the previous sections, every possible combination of room turnover time across the 5 endoscopy rooms was analysed. Figure 4.14 summarise the results.

4.3.3 Results of simulation

As mentioned above, the researcher observed differences between the processes described by the staff and the current working practices, as well as differences in the practices between different members of staff. In this project, and standard patient journey is assumed as follows: arrival; check in; waiting for admission; nurse interview (admission and consent form signature); waiting for procedure; endoscopy procedure; patient to recovery; patient monitored throughout the course of recovery; waiting to

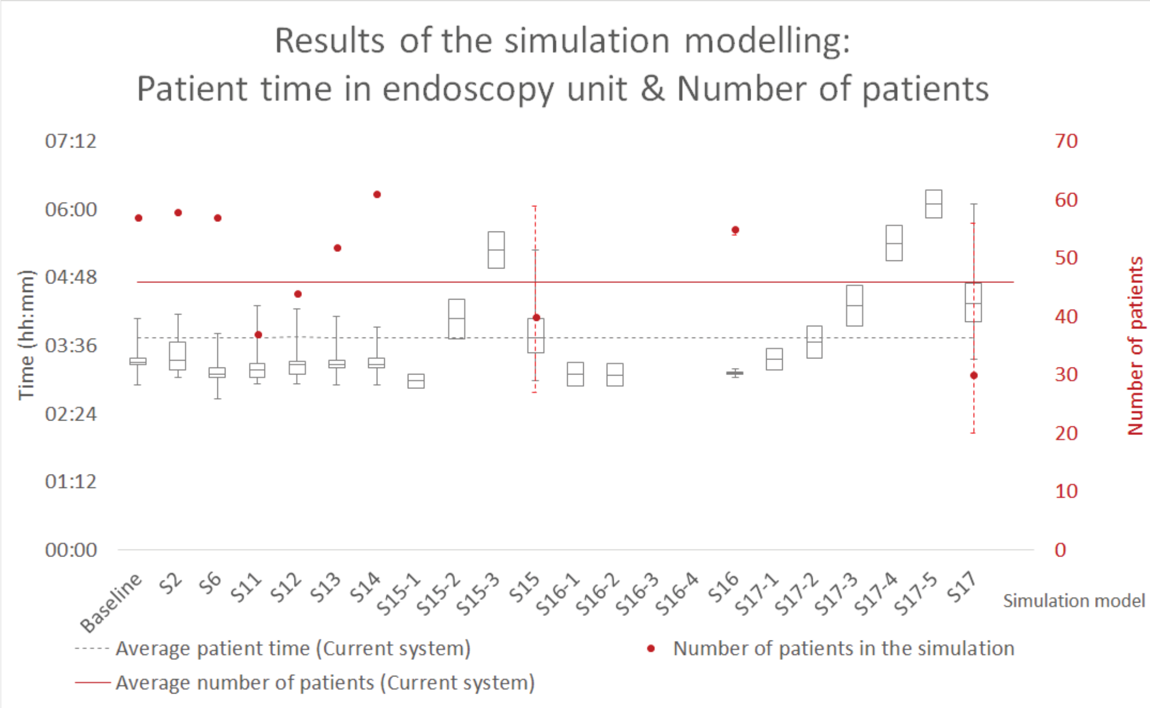

Figure 4.15: Results of the simulation modelling: Patient time in endoscopy unit and number of patients seen.

discharge; discharge.

Current patient and staff pathways across the endoscopy unit were modelled, and as detailed above, several scenarios were simulated. Detailed explanations on the rationale of the simulation model, parameter selection, as well as factors studied can be found in the Section 4.3.1 and 4.3.2.

Figure 4.15 and Tables 4.4 and 4.5 summarises the results of the simulation modelling, with the all the scenarios outlined in the Section 4.3.2.

The x-axis represents the set of scenarios analysed. The two y-axis represents the two KPIs used in this project to compare the results of the different interventions simulated. Left y-axis represents the patient time at the endoscopy unit in hours and minutes, and the right y-axis shows the number of patients seen in the simulation.

The patient time in the endoscopy unit is presented using a Box-and-Whisker charts, including the maximum, third quartile, media, first quartile and minimum value for the replications. The dashed line represents the patient LoS in the endoscopy unit based on a year of real data from the unit.

The number of patients are represented by red dots, with a solid red line presenting the average number of patients seen based on the retrospective data analysis.

Model ID	Individual simulation models (*)	Procedures performed/day	Patient time in endoscopy unit, h (95% CI)	Physician use, % (**)	Procedure nurse 1 use, % (**)	Admitting nurse use, % (**)	Procedure room use, %	Recovery bed use, %	Points use, %
Baseline	Baseline	55	3.4 (3.1-3.6)	53.6	56.5	33.2	52.1	31.7	72.1
Impact of endoscopy unit appointment time (1)									
S1	60-min: 9-10am, 2-3pm appointments	51	3.3 (3.1-3.5)	53.6	56.0	33.2	51.3	30.3	69.0
S2	60-min: 8-9-10am, 1-2-3pm appointments	55	3.4 (3.2-3.7)	57.9	60.4	34.5	54.5	33.0	74.0
S3	60-min: 9-10-11am, 1-2-3pm appointments	47	3.4 (3.1-3.6)	55.3	57.9	34.5	52.8	31.4	68.1
S4	30-min: 9-9.30-...-11.30am, 1.30-2-...-4pm appointments	47	3.0 (2.8-3.1)	53.8	56.0	33.7	51.7	30.2	69.0
Impact of recovery room time (2)									
S5	Recovery times mean: 15 minutes	57	2.9 (2.7-3.1)	53.5	56.4	33.2	52.1	13.6	72.1
S6	Recovery times mean: 30 minutes	57	3.1 (2.9-3.4)	53.6	56.5	33.2	52.2	22.7	72.1
S7	Recovery times mean: 45 minutes	55	3.4 (3.1-3.6)	53.6	56.5	33.2	52.1	31.7	72.1
Impact of recovery room time (3)									
S8	Recovery times mean: 15 minutes	51	2.5 (2.4-2.7)	53.9	56.0	33.7	51.7	12.8	68.1
S9	Recovery times mean: 30 minutes	49	2.8 (2.6-2.9)	53.6	56.0	33.7	51.6	21.7	67.2
S10	Recovery times mean: 45 minutes	47	3.0 (2.8-3.1)	53.8	56.0	33.7	51.7	30.2	69.0

Table 4.4: Individual simulation performed in the Frimley endoscopy unit model and calculated with regard to several performance and efficiency metrics.

(*) All the values and CI as averages over 10 replications / set of simulations.
(**) Staff hour required by staff role based on patient contact time.

(1) Baseline model: 120-min appointment, Patients appointment at 8-10 am, 1-3 pm.
(2) Based on Baseline model appointment system.
(3) Based on 30-min: 9-9.30- ... -11.30 am, 1.30-2- ... -4pm appointments.
(4) Based on 9 elective sessions per day, 12 points each session. One session per day is reserved for inpatient emergencies.
(5) Based on 10 elective sessions per day, 12 points each session.
(6) Set of 250 simulations (10 replications each) with Endoscopy procedure time means: 10, 30 or 50 minutes. 5 Endoscopy rooms.
(7) Set of 6000 simulations (10 replications each) with Admission time means: 2, 5, 10 or 20 minutes. 6 Admission rooms (male and female).
(8) Set of 3125 simulations (10 replications each) with Room turnover time means: 5, 10, 20, 40 or 60 minutes. 5 Endoscopy rooms.

Model ID	Individual simulation models (*)	Procedures performed/day	Patient time in endoscopy unit, h (95% CI)	Physician use, % (**)	Procedure nurse 1 use, % (**)	Admitting nurse use, % (**)	Procedure room use, %	Recovery bed use, %	Points use, %
Baseline	Baseline	55	3.4 (3.1-3.6)	53.6	56.5	33.2	52.1	31.7	72.1
Impact of new working practices (2)									
S11	Physician available between 8 am to 3 pm (4)	37	3.3 (3.0-3.5)	34.7	35.3	33.2	33.4	21.9	52.4
S12	Physician available between 8 am to 4 pm (4)	44	3.3 (3.0-3.6)	34.4	40.9	33.2	39.1	25.6	60.2
S13	Physician available between 8 am to 5 pm (4)	52	3.3 (3.1-3.6)	38.4	48.2	33.2	45.6	29.7	66.1
S14	Physician available between 8 am to 7 pm (5)	61	3.3 (3.1-3.5)	41.9	61.1	33.2	51.0	35.0	67.5
Impact of Endoscopy procedure time (2)									
S15	Endoscopy procedure times mean: 10, 30 or 50 minutes (6)	40 (27-59)	3.8 (2.9-5.6)	-	-	-	-	-	-
Impact of Admission time (2)									
S16	Admission times mean: 2, 5, 10 or 20 minutes (7)	55 (54-55)	3.1 (2.9-3.4)	-	-	-	-	-	-
Impact of Endoscopy room turnover time (2)									
S17	Room turnover time means: 5, 10, 20, 40 or 60 minutes (8)	30 (20-56)	3.2 (4.4-5.9)	-	-	-	-	-	-

Table 4.5: Individual simulation performed in the Frimley endoscopy unit model and calculated with regard to several performance and efficiency metrics.

(*) All the values and CI as averages over 10 replications / set of simulations.
(**) Staff hour required by staff role based on patient contact time.

(1) Baseline model: 120-min appointment, Patients appointment at 8-10 am, 1-3 pm.
(2) Based on Baseline model appointment system.
(3) Based on 30-min: 9-9.30- ... -11.30 am, 1.30-2- ... -4 pm appointments.
(4) Based on 9 elective sessions per day, 12 points each session. One session per day is reserved for inpatient emergencies.
(5) Based on 10 elective sessions per day, 12 points each session.
(6) Set of 250 simulations (10 replications each) with Endoscopy procedure time means: 10, 30 or 50 minutes. 5 Endoscopy rooms.
(7) Set of 6,000 simulations (10 replications each) with Admission time means: 2, 5, 10 or 20 minutes. 6 Admission rooms (male and female).
(8) Set of 3125 simulations (10 replications each) with Room turnover time means: 5, 10, 20, 40 or 60 minutes. 5 Endoscopy rooms.

4.4 Conclusions

This study applies systems modelling and simulations to identify interventions to improve the performance and patient experience in an endoscopy unit in Wessex. Using a mixed methodology, including process mapping, time motion study, interviews with members of the staff, analysis of data collected in paper-based forms, analysis of hospital Electronic Patient Records (EPR), and literature review for parameter estimation and training, the model predict consistently well the endoscopy process and patient LoS at the unit. For validation and continuous refinement of the model, we compare the simulated results against hospital statistics.

A bespoke modelling tool was developed for the demand and capacity analysis of the endoscopy service (at Frimley Park Hospital). The modelling enables trust teams to review different operational elements (e.g. patient arrival time, endoscopists working hours, staff roles) and evaluate the benefits on patient experience and department capacity, through making the best use of resources.

In this study, a DES of an endoscopy unit was developed to analyse the impact of different factors in the performance and efficiency of the unit including patient experience (represented as LoS at the unit). Several 'what if' scenarios were analysed, with constraints suggested by the project steering group (formed by clinicians and managers), for instance: maximum number of patients per day and scenarios with no extra investments required to the endoscopy unit. Other scenarios such as considering '2-endoscopists per room' were also excluded of the analysis following the steering group suggestion.

DES is one of the options to evaluate and improve a healthcare system, operational research provides several methodologies to apply analytical methods to make better decisions.

The study identified a limited communication with the patients, and enables the team to identify practice variance across different staff members and suggests some simple-to-implement recommendations. These includes standardisation in communication with patients and within the endoscopy unit staff, and in the administration process flows.

A revision of the protocols for the patient appointment scheduling is suggested. Scheduled start and finish times should also be reviewed on the site, as well as a causal analysis for delays to start the lists on time, as both have a huge impact in the prolonged times that patients are waiting at the endoscopy unit, mainly between the admission and procedure start.

A review of staff functions is also recommended; one of the reasons for delays to the start of the endoscopy procedure is because of patient transport to the recovery area by one of the procedure nurses. This could be solved with an assistant transferring patients between procedure room and recovery area.

Another suggestion is to review the flow of patients through unit; this could reduce the contact between pre and post-procedure patients and improve patient experience.

The point system used at the endoscopy unit should also be reviewed. Endoscopy services at the NHS uses a points system as a guide to convert the workload to a unit of time, with no standardisation across the country. As mentioned in a JAG's report, some units assign 15 minutes to one point, while others assign 18 or 20 minutes. In 2012, NHS Improvement published a report with best practices guidance for endoscopy services after a review of 14, the document identified the variation in activity between services as one of the key challenges that endoscopy services are encountering, with a large variation across sites and sessional activity between rooms of the same site. Other potential variations between sites are the session length (some units work with 4 hours for both morning and evening sessions, while others assign 4 hours for morning and 3.5 hours for evening sessions). There is also an important variation in the maximum number of points allocated to each list, with an accepted maximum 12 points per list, some units assign 12 points to morning sessions, and 10 to evening sessions, and with a planned activity that varies on a diary base. Points for training also vary, typically between 7 and 8. Different number of points are also allocated to procedures, e.g: 1 point for OGD, 2 for colonoscopy, and differents ways to adjust for case mix, training lists and emergency patients. Scheduled start and finish times are also different between endoscopy services across the country.

The analysis of 3 sessions per day was also excluded from the analysis as indicated by the manager arguing that 'a third session would not fit into the hospital structure'. Weekend sessions were also excluded of the analysis.

This study indicates that a review of the procedure planning process could result in a 10% increase in endoscopy room occupancy and an improved patient experience (reduced time spent in the department). A review of the emergency booking system and the possibility of obtaining patient consent prior to admission would also facilitate process improvements, as would an increase in flexible nursing roles (admission and recovery).

Session utilisation should be routinely monitored as low utilisation falls into 3 categories: insufficient backfilling of lists, high rated of do-not-attendances, and under/over booking.

Room scheduling options review is also recommended, for example to analyse the impact of 1:1 endoscopist to room rate versus 1:2 endoscopist to room rate, comparing the impact of endoscopy room turnover time with the endoscopist turnover time.

This study has several limitations. Observer variance, seasonal factors, and the *observer effect* - a reaction in which individuals modify an aspect of their behavior in response to their awareness of being observed. Training lists, and nurse endoscopist lists, where fewer points are assigned. Other staff functions as unit-related functions, and nonclinical activities are not included in the analysis. We believe that the next logical step is, therefore, the clinical verification of these findings.

There are several directions to further enhance our current simulation model. An analysis focussed on the patient time being scoped, versus patient time in the room/total list time, could be useful in order to analyse the importance of the turnaround time, and delays (patients, clinicians, and equipment). We can introduce additional variables into the analysis, for example costs, to evaluate the impact of the cost-effectiveness analysis of the proposed interventions. We can also, re-use the simulation model to evaluate future changes using a multi-criteria decision analysis approach. The methodology presented here, can be used to evaluate other services, and the simulation model developed can be re-used to evaluate other endoscopy units across the country.

Final outcomes from the modelling was presented to hospital managers as well as the Clinical Commissioning Group (CCG) manager. A evaluation of the implementation of the changes recommended over three months was agreed with the Trust. Feedback from the CCG shared at one of the Wessex CN Steering Group Meeting concluded that the work was of value. Key actions to be undertake by the Hospital as a result of the modelling are given below:

- Reviewing differing operational guidance and patient pathways with a view to identifying any further improvements, whilst affirming protocol.
- A number of utilisation audits have taken place using the modelling to check were and how the trust can improve intra and session utilisation.
- Considering differing skill mix both inside the endoscopy room and the unit itself.
- Patient flow including staggered start times: They currently operate staggered times for the patients, however, are looking to review these as they feel that

they have under estimated the amount of urology Two weeks referral (TWR) reserved slots available.

- The modelling highlighted a need to improve patient communication. Different improvements are being implemented.

This study has shown the potential value for further formal studies to quantify and optimise existing endoscopy capacity before major investments in extra capacity, with a potential improvement in the patient experience, and in the staff, accomplishing the same amount of work in less time.

As a result of this project, system modelling is now being undertaken across other endoscopy units in the region, and the simulation model here developed is being re-used. A framework to generalise the proposed methodology was also developed and it is currently being tested across different hospitals to be used as a toolkit to evaluate and improve the process across all cancer diagnostic services across the Wessex region in southern England, UK.

4.5 Chapter Summary

Section 4.1 introduced the problem and research aims. Section 4.2 described the methodology used in this study, and presented the endoscopy unit analysed, including process mapped, data collected, and the simulation model developed to evaluate the unit. Section 4.3 summarised the 'what if' analysis, including results of the simulation. Finally, Section 4.4 presented conclusions and impact of this study.