Elective Pathway Modelling

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EXECUTIVE SUMMARY

Aims

The specific aim of this study was to model the flow of patients through the steps of the elective pathway within the Gynaecology service in Cardiff & Vale University Health Board in order to allow service managers to predict demand. The development of a simulation model was intended to enable the identification of delays and long waiting times in the system (bottlenecks), testing scenarios to solve these problems and evaluating the best scenarios.

Background

Elective treatment is defined as planned in advance treatment. Typically, elective treatment consists of outpatient appointments, admissions (such as a day case operation or inpatient admission), follow-up appointments and other procedures which are related to outpatient treatment. The Gynaecology service consists of main three pathways which are Parent Gynaecology (Urgent-Routine), Gynaecology-Oncology and Urodynamic pathways according to information which is attained from service administrator and dataset.

Methods and Results

Discrete event simulation was used to model the Gynaecology service. The model development process was carried out in two parallel stages: data analysis and simulation model building. In the data analysis stage, data was organized by utilising some data mining and data grouping techniques. Descriptive statistics were attained and distributions and quantification of transitions between stages in the model were identified through the analysis. Additional data analysis which helped to convey the understanding of the system obtained, but not pertinent to the simulation model, was presented to the stakeholder during the project. In the other stage (simulation model building), a model was built by using Simul8 software and populated with the data which was found in the data analysis stage. Finally, a verified and validated model was achieved following testing of the model and discussions with stakeholders. Four scenarios are tested to decrease waiting times of patients and to identify potential improvements to the Gynaecology Department. Scenario 1 tested the impact of including an additional clinic for new patients only and for new and follow-up patients.

Increasing ‘new’ patient capacity leads to more patients in the follow-up cycle which the department is already struggling to see in a timely manner. Therefore, adding a clinic for new outpatients needs to be balanced with an additional follow-up clinic or a clinic which is added to system should be served for both new and follow up patients to improve the system. In scenario 2, the effect of treatment durations are tested and the treatment durations of new and follow-up patients were decreased. The results shows that decreasing treatment durations helped to shorten waiting times and delays and it made the system very effective. In scenario 3, some follow-up clinics were shifted as virtual review clinics (which have shorter treatment durations) in order to see the impact of virtual review clinics. It significantly decreased delays in all pathways. Moreover, not only was a reduction in follow up delays observed, but also a reduction in waiting times for new outpatient appointments in Gynae-Oncology and Urodynamic pathways as resources are shared based on the volume of new and follow appointments in these pathways. Finally, scenario 4 tested the impact of adding one nurse led clinic (which serves for all pathways). As a result of this scenario, nurse led clinic was found very useful to cope up with delays. In addition, all follow-up delays and waiting times for new outpatient appointments reduced in Gynae-Oncology and Urodynamic similar to scenario 3.

Findings

The total number of new outpatients which explains the total demand for Gynaecology service in 3 years was found as 53,250. Moreover, it has been seen that most patients who are required follow-up appointment are accepted in ‘less than 1 month’ time period for their follow up appointments in urgent and gynae-oncology pathways. However, in routine and urodynamic pathways, most patients are accepted ‘between 1 and 3 months’ time period for their follow-up appointments. The number of inpatients was found as 9,586. Furthermore, total 15,856 patients disappeared in the system because of the reasons such as “did not attend (more than once)” or “transferred to another H\C professional” and total 32,958 patients were discharged in 3 years. Waiting times of new outpatient appointments are another component to evaluate demand for services at each stage. According to simulation model outcomes, new outpatients wait average 27 weeks for their first outpatient appointments in Routine pathway. However, there is no significant delay for follow up appointments which are in different time periods in this pathway. In Urgent-Parent Gynaecology pathway, new

outpatients wait average 7.5 weeks for their first outpatient appointments. Moreover, it has been found that overdue rate (the delay represented as percentage of the Pause which is the predetermined waiting time) of 'less than 1 month' follow-up time period is quite high, but the total waiting times of patients for this time period do not go beyond 1 month. On the other hand, the overdue rates for other time periods in the urgent pathway are less than 1 percent. The waiting times for new outpatient appointments is found as average 2 weeks for Gynae-Oncology and 8 weeks for Urodynamic pathway. Moreover, delays of follow-up appointment time periods are less than one week in both pathways. Additionally, all scenarios facilitated to improve the current system, though decreasing treatment durations (scenario 2.1) was found as the best simulated scenario. However, this scenario may not be wholly achievable and was used to illustrate the perfect situation and understand the importance of treatment durations. On the other hand, shifting some clinics as virtual review clinics (scenario 3) was determined as the most feasible scenario in terms of eliminating follow-up appointment delays and adding one extra clinic to the system(scenario 1.2) was seen as one of the best scenarios to shorten waiting times of new outpatients in the Gynaecology department.

Conclusion

The simulation model and results were found to be considerably consistent and met the expectations of the stakeholder. It can be said that the Gynaecology department is close to meet government waiting time targets, especially for non-routine pathways. However, waiting time for follow-up appointments are longer than planned waiting time. Developing some strategies which focus on Urgent Parent Gynaecology pathway as it is the busiest pathway and solve bottlenecks in the follow-up appointment time periods which is less than 1 month as it is the busiest time period will be more useful to increase efficiency of department. Moreover, the scenarios which were produced in this study can be applied to make the system more efficient. Furthermore, the scenarios can be combined with each other in order to solve different problems on the system. Consequently, the study illustrates the bottlenecks and patient flows in an elective pathway model which is rarely seen in literature. In addition, the study presents a model which can be used as a tool by the service managers to set a course for the department.

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SUMMARY

The specific aim of this study was to model the flow of patients between stages of the various pathways within the Gynaecology service in Cardiff & Vale University Health Board in order to allow services managers to predict demand. However, the modelling was done based on elective care (elective treatment) which is explained as planned in advance treatment.

Gynaecology service consists of main three pathways which are Parent Gynaecology (Urgent-Routine), Gynaecology-Oncology and Urodynamic pathways. The modelling process consists of two stages which were the data analysis and simulation model building. In data analysis stage, data was identified and prepared to use in the model. In the simulation model building stage, a discrete event simulation model was built by using the Simul8 software. After model building and testing steps, main four scenarios are tested to decrease waiting times of patients and to identify potential improvements to the Gynaecology Department.

As a result of the simulation model, it is found that more than 17,000 patient comes to Gynaecology department in a year and most of them follow Urgent Parent Gynaecology pathway. Moreover, the department generally meets new outpatient waiting time targets, especially in non-routine pathways. However, delays are found in follow-up appointments and it causes longer waiting times for follow up appointments. Especially, `less than 1 month` follow-up time period in the Urgent pathway is found as the busiest follow-up time period of the department.

As a result of scenarios, it is found that all scenarios improve the current system, but decreasing all treatment durations was defined as the best scenario. Furthermore, shifting some clinics as virtual review clinics was determined as the best scenario to eliminate delays in follow-up appointments and adding an extra clinic to the system was found as the best scenario to decrease new outpatients waiting times.

1. INTRODUCTION

Healthcare modelling is one of the most important issues in healthcare studies because of its contributions to efficiency of systems. Hospitals or departments which want to improve their healthcare systems primarily focus on predicting the demand for services. This is because analysing and understanding demand to detail can help healthcare administrators when they develop a strategy in order to decrease waiting times, solve bottlenecks and make the system more efficient. In elective treatment which is defined as planned in advance treatment, the patient may be required to attend the hospital for some potentially non-sequential steps in their pathway. Therefore, predicting demand for services at each stage gain importance in an elective pathway. This study aims to model the flow of patients between stages of the elective pathway within the gynaecology service in Cardiff & Vale University Health Board in order to allow service managers to predict demand.

The study consists of six sections apart from the introduction. Section two gives information about the background of the study. Therefore, the organisation which is Cardiff and Vale University Health Board is presented first and Gynaecology Service is explained with its units. In addition, some definitions which are used in this study are presented in this section.

Section 3 contains literature review which present information about previous scientific studies on this subject. This section is divided into four main parts which is 'the introduction', 'the importance of healthcare modelling and simulation', 'pathway modelling' and 'gynaecology services pathway modelling'.

Section 4 provides methodology which clarifies methods that are systematically applied in this study. This section, which is the largest section of the study, consists of two main steps which are the data analysis and the simulation model. In the data analysis step, the data source, the data period and process and descriptive statistics which is divided into two section (analysing the model contributing data and analysing data to be used in simulation model) are presented. In the simulation model section, simulation software and process, simulation objects, overall model construction, model assumptions and what if scenarios are clarified.

Section 5 presents the results of the study. This section consists of three parts. At the first part, the verification and the validation of the model are explained. At the second

part, simulation model results are presented in detail and in the final part which is the ‘what if scenarios results’ are explained.

Section 6 provides discussion. In this part, analyses, model results and what if scenarios results are discussed and scenarios are compared with each other. Some suggestions are made to improve the efficiency of the system. Moreover, limitations of this study are explained.

Section 7 consist of two titles which are the conclusion and the future works and this section provides an overall conclusion which presents the key points emerging from the study and suggestion for further research.

2. BACKGROUND

2.1. The Organization

One of the major NHS organisations in Wales is the Cardiff and Vale University Health Board (CVUHB) which serves a population of around 472,000 people living in Cardiff and the Vale of Glamorgan. It also serves the population of Mid and South Wales for a variety of specialist medical services. CVUHB takes “caring for people, keeping people well” as a mission and “to create a community where the person`s healthy life chance does not depend on who the person are or where the person lives” as a vision. Additionally, Cardiff and Vale University Health Board has close relations with the university sector so the Health Board trains the next generation of healthcare professionals as well as researching to improve treatment methods and developing the cures for illnesses. Detailed information can be attained by using statistics. According to 2014 statistics, Cardiff and Vale University Health Board employs approximately 14,000 staff, helped 138,016 to access A&E, assisted 127,807 people at out of hours services, performed 299,114 X-Rays, carried out 5,006,139 blood tests and dispensed 3,795,863 prescription items. Also, 973,425 patients have contact with the hospital, 672,660 patients have contact with community staffs, and 14,105 people have access to mental health services (CVUHB 2014).

2.2. Gynaecology Service

Gynaecology is the medical practice that deals with the health of the female reproductive system. The gynaecology service at CVUHB is quite a busy service with more than 2,000 patients annually for a surgical operation and more than 16,000 new patients or follow-up outpatient consultation. Gynaecology service at CVUHB consists of an Early Pregnancy Assessment Unit, an Emergency Gynaecology Assessment Unit, an Uro-Gynaecology department, a Gynaecology Oncology unit (the Women's Cancer Centre for Wales), Gynaecology In-patients clinics and Gynaecology Outpatients clinics (CVUHB 2015). The units and clinics which are explained in subtitles are based on the CVUHB Gynaecology service website and service expert views.

2.2.1. Early Pregnancy Assessment Unit

The Early Pregnancy Assessment Unit (EPAU) is an integrated single unit that admits referrals from all over Cardiff and the Vale of Glamorgan. The unit staffs are skilled in the management of early pregnancy complications containing ultrasound scanning. Minimising redundant hospital admissions is the main objective of the unit. GP's or Gynaecology wards mainly refers Patients to the Unit.

2.2.2. The Emergency Gynaecology Assessment Unit

This unit provides rapid access to medical treatment for women who have acute early pregnancy problems and experience to any women who have had an emergency appointment to the gynaecology unit.

2.2.3. Uro-Gynaecology department

The department of Uro-Gynaecology ensures all-inclusive multidisciplinary service for women. The department supplies clinical assessment for women with various situations or complaints such as Gynaecology problems, Lower urinary tract dysfunction who is referred by their GP or Obstetrician.

2.2.4. Gynaecology Oncology Unit

The Department of Obstetrics and Gynaecology includes in The Women's Cancer Centre for Wales. Therefore, the unit is part of the South Wales Cancer Network. For South East Wales and parts of South West Wales, a gynaecological oncology tertiary referral service is provided by the unit. Together with an experienced multi-disciplinary team, five consultant Gynaecological Oncology sub-specialists provide the highest care standards for patients and their relatives. The service consists of 19 inpatient beds, outpatient clinics and nurse practitioner-led pre-assessment clinics. Most hospitals in West and South Wales are in coordination with the service; hence more than 70% of the clinical workload is from outside Cardiff.

2.2.5. Gynaecology In-patients wards

Gynaecology service at CVUHB has 3 daybeds, 5 emergency beds and 19 surgical beds. All major and minor surgeries which involves urogynaecology, endometriosis, emergency admissions, and emergency surgeries are operated in the clinic. Furthermore, care and support for women and their families which suffer from

miscarriage and termination of pregnancy is provided by these clinics in cooperation with EPAU and Fetal Medicine. GP's refer patients to these clinics directly.

2.2.6. Gynaecology Outpatients clinics

Gynaecology outpatient clinics are free from Monday to Friday and the out-patient department consists of different clinics which are Nurse-led hysteroscopy, pessary, pre-admission, family planning and cervical smear clinics. Different consultants and teams help patients in each clinic.

2.3. Definitions

2.3.1. Integrated Care Pathway

Integrated Care Pathway is defined as a tool and an idea, which includes guidelines, protocols and best practices which are based on evidence, in everyday use for patients (Cumming ed. 2005). The aim of integrated care pathway is explained by De Blaser et al. (2006) as improving the quality of care, diminish risks, enhance patient satisfaction and improve the efficiency in the use of resources. Simplistically, Integrated Care Pathway which is also called Clinical Pathways, Multidisciplinary Pathways of Care, Collaborative Care Pathways, Care Maps and Pathways of Care states "the path" that is followed by a patient through the health-care system. This path can be thought at a single level of care such as inpatient care, outpatient care and home care or globally known as all levels of health-care from education and prevention to diagnosis, treatment and recovery (Ozcan et al. 2011).

Integrated Care Pathway ought to consist of activities which are the planned elements of care contained in the process and the detail which are tools or descriptions such as observations, fluid balance charts, demographic details, outcomes (which are clinical outcomes i.e. tests), process outcomes, patient or staff outcomes and finally variance tracking which can be defined and allows to compare planned and actual care and to lead continuous development of practice. (Cumming ed. 2005).

2.3.2. Elective Pathway Modelling

Elective care or elective treatment is explained as planned in advance treatment which is the contrary to emergency treatment. Typically, elective care consists of outpatient appointments, admissions (for example a day case operation or in-patient admission

for a long duration procedure which means the patient needs to stay one or more nights in hospital), follow-up appointments and other procedures which are related with outpatients.

Elective Pathway Modelling is very similar to Integrated Care Pathway in terms of the main idea and objectives which they are used in. However, Elective Pathway Modelling focus on non-emergency or planned care and a specific field or clinic. The aim of Elective Pathway Modelling is to improve healthcare by understanding the flow of patients through the steps and helping the clinic staff to estimate the demands for the services at each stage.

2.3.3. Referral to Treatment Time

Referral to Treatment Time (RTT) is defined as the time period from referral by a general practitioner (GP) or another medical practitioner to the hospital for treatment. A referral to treatment pathway involves the waiting time from the referral to hospital for treatment and contains time that is spent by waiting for any hospital appointments, scans, tests or other procedures which may be required before treatment. In Wales, 95 per cent of patients waiting less than 26 weeks from referral to treatment and 100 percent of patient (not treated within 26 weeks) treated within 36 weeks, therefore the targeted referral to treatment times are mostly met to timely access to planned services (Welsh Government 2016).

"A guide to good practice - Elective Services" which is published by National Leadership and Innovation Agency for Healthcare and edited by Cumming (2005) is mainly utilised for the following definitions on the purpose of using the main source which is defined by NHS.

2.3.4. Did Not Phone, Did Not Attend and Could Not Attend

If the patient does not phone in response to a partial booking letter or a validation letter, he or she can be deleted from the waiting list. Hence, the reason is defined as "Did Not Phone" or 'DNP'.

If a patient does not attend to the admission or the appointment without informing the hospital, the patient is recorded as Did Not Attend (DNA).

If a patient notifies to the hospital that he or she cannot attend the appointment or the admission, the patient is recorded as Could Not Attend at the end of the day.

2.3.5. The Four Measures: Activity, Backlog, Capacity and Demand

Activity, which informs the number of patients that are seen in the clinic, processed to theatre or discharged from the ward, is the output of the system. It should be converted to the common unit of measure so it is measured by using the following method; the total number of patients are found and multiplied by that time.

The backlog, which adapts the waiting list to the common measure, defines the number of patients on the waiting list or the patients that refused admission. As it is done for the activity, it is converted to a common unit of measure by using the same method as the activity.

Capacity is defined as the maximum limit of sources. Therefore, the system capacity is the time which the sources are available. The staff working hours or theatre using hours can be exemplified for capacity.

The demand for service is defined as the patients are referred to the service from the general practitioner (GP) or another medical practitioner. Due to comparison of the demand with activity and capacity, the demand should also be converted to time. In addition, some other measures such as bed nights, diagnostic machine use and clinic times can be used.

2.3.6. Constraints and Bottlenecks

The constraint in the system is the phenomena which restrict the capacity of the system e.g. space can be a constraint for outpatients. Without investing in staffing or facilities, the constraint is not eliminated easily. Therefore, the constraints should be identified clearly to understand the service.

Bottlenecks define a situation which causes delays in the system and it affects the flow. So, bottlenecks are one of the main reasons for the failure of the system. However, bottlenecks are removed easily without any requirements of any investments. Consequently, constraints limit capacity whilst bottlenecks limit activity. Therefore, the activity can be enhanced by removing bottlenecks until it reaches the capacity of the system.

3 .LITERATURE REVIEW

3.1. Introduction

The literature review gives comprehensive information about previous scientific studies on a subject. Therefore, the aim of this section is to broadly provide healthcare modelling and simulation related literature by using ‘from the general to the specific’ methodology.Due to developing computer simulation especially in fifteen years, the review focuses on scientific papers which are published in the last fifteen years. However, the scope of the literature review extent to the theoretical or review studies which is done before 2000 years to explain the core of the theory or the historical improvement of literature.

As a searching method, backward and forward searching techniques were utilized; hence firstly, prior articles are determined as backward searching and later, forward searching were applied to enlarge searching. The literature search was carried out by using Ovid, Scopus and Google Scholar databases. In these databases, some keywords and word groups such as “simulation”, “elective pathway”, “modelling”, “scheduled treatment”, “patient pathway”, “gynaecology”, “discrete event simulation”, “Markov” and “transition matrices” were used in different combinations. As a result of database searching, three books and forty-two related articles were identified from a large number of articles were found and they were tabulated according to its relation ranking. In addition, hard copy based catalogue researching was done in Senghennydd Library, Cardiff University.

The literature review is organised in four main sections which is the ‘introduction’, the ‘importance of healthcare modelling and simulation’, ‘pathway modelling’ and ‘gynaecology services pathway modelling’. These sections are decided according to paper groups. In all of the sections, a brief theory definition and explanation of the subjects are provided before providing subject related studies.

3.2. Importance of Healthcare modelling and Simulation

Finding new methods and models or increasing efficiency of health care systems are main concerns for healthcare researchers. Operational Research methods which seek to achieve better solutions are commonly used for this aim. One of the most popular

operational research methods applied to healthcare modelling is simulation, which is also widely used in manufacturing, logistics, and the military.

The importance of simulation in healthcare is growing due to the flexibility in modelling complex patient flow and time-dependent performance of a system. (Bhattacharjee and Ray 2014). Furthermore, simulation is appropriate to compute a lot of operational performance measures (*ibid.*, p.309). Simulated models mirror the present situation of the service facility and the patients' situation in pathways. However, the most important feature of the simulation is that it enables to test different scenarios which are called "what-if scenarios" without changing the running system. Additionally, simulation gains importance when there are uncertainty and changeability in the system. This is because it easily integrates other operational research methods such as optimization. Consequently, simulation techniques assist hospital executives or clinic administrators to see the consequences of possible variations in the clinic without breaking the running system or occupying any resources (Thorwarth and Arisha 2009).

In recent years, analysing and modelling of healthcare system has come into prominence as the system requires more improvement over time to meet a lot of objectives and goals which can be exemplified as minimizing the healthcare cost, maximizing physical and human resources or adapting varieties of healthcare facilities in a single location as well as increasing patients demand (Bhattacharjee and Ray 2014).As a result of this situation, studies on healthcare modelling and simulation have increased in recent years.Another significant factor in increasing healthcare modelling and simulation studies is that computer technology has been increasing day to day. It is clear that developing computers provide more accurate and fast simulation results and these improved results motivate researchers to cope with more complex models. Thorwarth and Arisha (2009) states that the publication rate of healthcare simulation papers has doubled within the last decade. They showed that while only eight paper were published between 1973 and 1977, twenty-eight publications were published between 1993 and 1997 and finally sixty-two papers were published between 2003 and 2007.

Gunal and Pidd (2010) resplendently explain the reviews on simulation in the history. As they mention in this study, one of the first reviews is published by England and

Roberts (1978) and they investigated 92 studies which are related to the simulation model in this study. Therefore, their paper looks through the history of simulation and shows the other modelling methods in healthcare. Gunal and Pidd (2010) states that research efforts mostly failed during the application stage since balancing conflicted objectives of doctors, directors, hospital administrators, nurses, and other health-care professionals could not be successful. However, they also emphasize some studies which include successful models despite the lack of progressed computers. One of these studies which is done by Smith-Daniels et al (1988) examine capacity management in health care, including simulation. In terms of review studies, Gunal and Pidd (2010) states that the last two reviews most recently in the past which are published by Jun et al (1999) and Fone et al (2003) are more inclusive and methodical than the previous studies. They involve approximately the same time period. Nonetheless, they examine quite different methods. Especially, the reviews which are studied in the last 10 years have importance since simulation applications were increased due to developing computer technology together with simulation software. Another remarkable reviews are published by Thorwarth and Arisha (2009), Aboueljinane et al. (2013) and Bhattacharjee and Ray (2014).

3.3. Pathway modelling

Basically, pathway modelling is a process to understand and improve patient flow, which is defined as the movement of patients from beginning to end of the whole caring process in a healthcare system. This definition can be detailed to explain the main idea clearly. When the patient arrives to the hospital, the flow of a patient starts and following this, the patient may be directed through a number of paths depending on the patient`s medical condition (Bhattacharjee and Ray, 2014).

Characteristics and components of a patient flow network are clearly explained by Bhattacharjee and Ray (2014). According to this study, queueing networks is used for the flow of patients through a hospital system so elements or building blocks of patient flow networks comprise the network structure that includes an entrance point, an exit point, many single or multi-server nodes between these points, the paths for connection, the patients and the resources. Any kind of patient flow can be explicated as a multistage/multiphase process, generally. (Hulshof, Kortbeek, Boucherie, Hans, & Bakker, 2012 cited in Bhattacharjee and Ray, 2014). Nonetheless, all the defined

stages in a care pathway may not be travelled by a patient. Typical activities at each phase contain arrival, wait, treatment, and exit. Also, precedence connection between some of the stages may not exist e.g. some of the activities may take shape in parallel lines (Jiang & Giachetti, 2008 cited in Bhattacharjee and Ray, 2014). On the other hand, patient flows have innate uncertainties and complexities (Cote, 2000). The main uncertainties stem from the randomness in the inter-arrival times of patients, service times and vagueness in the transitions between different stage locations and patient's health status; however, both seasonal and local causes in addition to the location of hospitals and presented services types affect the patient flow rate in a system (Alexopoulos, 2008 cited in Bhattacharjee and Ray, 2014). However, carefully and well-structured analysis of patient flows might decrease the bottlenecks and significantly progress the performance of a hospital system. Therefore, a lot of study on pathway modelling focus on patient flow in different areas.

A number of pathway modelling methods such as Discrete Event Simulation, System Dynamics, Agent Based Simulation, Monte-Carlo Simulation and Markov modelling are used in literature. However, Discrete Event Simulation can be seen as the most common used technique as mentioned in the next section. Furthermore, Discrete Event Simulation is used as the main simulation method of this study. Due to these reasons, the pathway modelling subtitle of the literature review section is detailed in two subsections. At the first following subsection, papers which are related to Discrete Event Simulation are examined. At the second subsection, papers which are related to the other simulation methods (which are mentioned above) are reviewed.

3.3.1. Discrete Event Simulation

Discrete-Event Simulation (DES), which models the process of a system as a discrete sequence of activities or events in time, is one of the most powerful and effective tools for modelling and improving a process. DES is used to assess performance, forecast the effect of operational modifications and inspect the trade-offs between system variables by healthcare managers and researchers (Abo-Hamad and Arisha 2013). Moreover, DES is utilized to find areas of improvement of service through possible redeployment of current resources and to plan locations of the new healthcare services, considering the demographics of the population and the region which people need the services (Abo-Hamad and Arisha 2013).

Discrete event simulation enables to model individual patients and their distinctive paths and to integrate wide range of different patient characteristics such as disease phase, gender and age. In addition, it gives an opportunity to run the model over an extended time preference (Demir et al. 2016). Besides, Discrete Event Simulation allows the flexibility to clearly combine resource and capacity constraints.

In literature, a great number of resources which is related to the application of Discrete Event Simulation in different areas in healthcare has been published. Werker et al. (2009) illustrate discrete-event simulation modelling of radiation therapy planning processes and they explain the model construction phases for similar models. Also, they demonstrate that using simulation at the radiation therapy to decrease process times and delays for treatment is quite possible.Because they found that changes to one small part of the treatment process affect the system improvement nearly 25%. Villamizar et al. (2011) aimed to make a discrete-event model to scrutinise the performance of a physiotherapy clinic in the city of Rio de Janeiro, Brazil.After they produce the original model to replicate the actual system of the clinic, they developed five simulation strategies which represent variations in the patient's number, human resources and patient arrivals.As a result of this model, the capacity of the clinic and other simulation strategies are successfully analysed.Parks et al. (2011) demonstrate the usage of discrete-event simulation in an adult medicine clinic within a large, tertiary care, academic medical centre.An urban eight-story outpatient medical centre which is annually visited by over 400,000 patients was carried out. In this study, simulation steps which contain information gathering, process mapping, data collection and model creation are explained clearly. It was seen that staff work overtime and clinic working hours are broadened to clear patients who are left in a work queue at the end of the day.Owing to the simulation model, they found that matching resources to excessive demand at the proper times for bottleneck steps decrease patients' mean time in the system from 124.3 minutes to 87.0 minutes. Komashie et al. (2008) showed the usage of Discrete Event Simulation in modelling the multifaceted relationship between patient sorts, case-mix and operating theatre apportionment.They performed the simulation for a large National Health Service (NHS) hospital in London.After they build a model, they tested three scenarios of case-mix and stated that simulation is one of the most effective methods in terms of cost to recognize the problems of healthcare management.Because the results show that

eliminating all day cases decreases patient throughput by 23.3% and the use of the orthopaedic theatre by 6.5%.

In some studies, different techniques are used in addition to discrete event simulation methods. One of this paper, which can be an example to these studies, is published by Abo-Hamad and Arisha (2013). Developing an interactive simulation-based decision, support framework to progress planning and efficiency of healthcare is aimed in this study and an emergency department in one of the largest University Hospitals in Dublin is modelled as a case study. The methodology that is used in this model is quite different and interesting when comparing with other simulation studies. In this study, balanced scorecard (BSC) which is used as a performance management tool is included in the simulation-based decision support framework to support steadily and sustainable progress by utilizing strategic-linked performance measures and actions. The actions are analysed by the simulation, while the adjustment between objectives is done by a preference model which is designed according to preferences of decision makers. Comprehensive application of the framework is exemplified on an emergency department. They discover that the unblocking of emergency department outflows by in-patient bed management is more advantageous for the department in terms of efficiency than growing only the physical capacity or workforce of the emergency department. As a basis, improving the clinical processes performance by using clinical pathways is aimed in Ozcan et al. (2016) study. However, developing a decision support tool, which is simulation and optimization method based, identifying the best strategy to reach better performance in terms of patients and the healthcare facility are specially targeted. They attained data from Department of Surgery of a public hospital which is in Genoa, Italy. The simulation model is developed to comprehend the pathway of the thyroid surgical treatment together with the other surgery-based clinical pathways. They evaluated the performance of pathway both from the patient's perspective and the provider's perspective. They argue that the main contribution of the study is that although the paper is a case study application, the simulation-optimization framework which is detailed explained in the study could be applied to other types of surgical clinical pathways and diseases studies. Another study is done by Ahmed and Alkhamis (2009). In this study, they examine patient flow throughout emergency department unit at a government hospital in Kuwait and assess the effect of alternative distributions of staff. The significant attribute of this study is that they

combine different techniques to achieve more than one aim. They followed a methodology which utilizes simulation together with optimization to find out the optimal number of hospital staff such as doctors, nurses and lab technicians to maximize the number of patients who are treated and to decrease patient time in the system, considering budget restrictions. At the final step, they attained the results that the model allows optimal staffing distribution to a 28% rise in patient output and approximately a 40% decrease in the patients' waiting time.

Some simulation models include in elective treatments. Demir et al. (2016) investigate demand and capacity modelling for acute services by using discrete event simulation. For this goal, firstly, they developed a decision support tool in their studies. Then they built a discrete event simulation model to evaluate individual patient pathways in 'accident and emergency', 'outpatients' and 'inpatients' until they are discharged. Also, the model is structured for elective and non-elective patients. The decision support tool provides to be compared with key performance metrics for a lot of different scenarios with current service situation. Therefore, they tested 6 scenarios and found that the bed capacity which is required has gone up by approximately 16% for all scenarios. They concluded that the hospital should plan to increase the bed capacity over a 5-year period. Another elective pathway related study is published by Antonelli et al. (2014). They applied Discrete Event Simulation to understand the effects of interventions on bed allocation and on pre-hospitalization for an elective surgery department in a hospital in Italy. For this aim, they mined and analysed the main factors which affect the patient flow and attempt to discover key solutions for improving the system's performance. After classical simulation methodology is applied, they found that a slight variation on the average of inter-arrival times causes for noteworthy variations on waiting times as a consequence of simulation.

In addition to these studies which are explained, Huarng and Hou Lee (1996) looked in out-patient queues, Cardoen, and Demeulemeester (2007) evaluated the capacity of clinical pathways, Landa et al. (2013) analysed bed re-organization at a surgery department, Feyrer et al. (2006) examined process optimization in cardiac surgery, Bowers et al. (2005) surveyed outpatient capacity for a diagnosis and treatment centre and Harper and Gamlin (2003) studied outpatient waiting times by using Discrete event simulation.

3.3.2. Other Simulation Methods and Approaches

System Dynamics, Agent Based Simulation, Monte-Carlo Simulation and Markov modelling can be defined as the most used simulation methods as well as Discrete Event Simulation. System dynamics is a method to develop strategy analysis and design. It is utilized for dynamic problems which include complex systems such as healthcare modelling. The System Dynamics process consists of two stages. The first stage is qualitative which the components of the system are designated and potential cause-effect relations are drawn in the shape of interconnected feedback loops. The second phase includes the transformation of the qualitative structure into a quantitative simulation model that the variable states and flows are defined and their relationships quantified after what if scenarios are analysed like in any simulation methods (Demir et al. 2016).

The System Dynamics methods act differently when compared with Discrete Event Simulation in healthcare modelling. Although individual objects disappear and patient transform as an indistinguishable mass that flows in the model, System Dynamics has numerous key features which cannot be included in Discrete Event Simulation. Because the main idea of System Dynamics is that "structure determines behaviour", in other words, the emergent behaviour of the system can be understood as a whole by understanding the structural relationships between the components of a system (Brailsford, 2007). One of the studies which explain the usage of system dynamics in the complex and extensive system is carried out by Brailsford et al. (2004). They applied system dynamics methods to the entire emergency system and on-demand health care in Nottingham, UK. For this aim, they firstly created a conceptual map of the system which demonstrates patient pathways by taking the thirty key individuals views in healthcare. After then, a stock-flow model was developed as a simulation model to understand patient flow and system bottlenecks and some scenarios are tested. As a consequence, they found that decreasing elderly patients for emergency admissions significantly affect bed occupancy. Additionally, a broad system dynamics literature review is provided in this study. Especially, a lot of paper which focus on system dynamics applications in the A&E department are explained. Another remarkable paper on system dynamics is published by Maliapen and Dangerfield (2009). In this paper, the progress of clinical pathways in a hospital in Australia is examined. For this aim, the decision support system is built and analysed by using

system dynamics techniques. Classically, some scenarios which assist hospital administrators to reallocate caseloads to clinicians are tested and evaluated. In that stage, diagnostic-related groups (DRGs) which are one of the well-known classification systems are utilized in a case mix funding model that is a government funding model. As a result, Maliapen and Dangerfield (2009) states that the system dynamics method which is based on the decision support tool is quite beneficial for healthcare administrators in terms of allowing to discover the potentials of clinical pathways.

Agent-Based Simulation evaluates systems in a different way when comparing with Discrete Event Simulation and System Dynamics. An agent is a self-directed object which can make decisions and hence the main goal of Agent-Based Simulation is to model the decision-making process (Demir et al. 2016). In other words, it examines that how a decision is made. Fundamentally, individual activities of an agent are modelled and following this, multiple entities are located in the environment so as to observe its interaction with others and the environment (Macal and North 2010). These interactions show the general situation. As Demir et al. (2016) states, although Agent-Based Simulation is often utilized to model of any disease spread, some researchers apply it on different topics such as modelling patient choice in healthcare systems. One of the Agent-Based Simulation based studies on clinical pathway is studied by Li et al. (2010). They aimed to develop a multi-agent modelling method to improve the capacity of clinical pathway. For that purpose, they explain a semiotic approach to evaluate the necessity of clinical pathway. Finally, the developed method is applied on the clinical pathway of breast cancer as a case study.

Markov chain which is also called as discrete-time Markov chain is a stochastic process which includes transitions from one state to another state. These states are defined as finite or countable and depend only on the present state so they are not dependent on the past states. In addition, a semi-Markov process defines as a Markov process which the duration between following transitions fit a specific probability distribution. A classical patient flow in a system which indicates any department or whole hospital contain some states which change during the process, hence Markov chains may be used for patient flows. Bhattacharjee and Ray (2014) argues that models that are built by using Markovian methods enables to determine the patient number in different stages at a specified time in the future and to analyse the lengths of stay for

inpatients or the time spent by a patient in different states during an outpatient treatment. Therefore, it may assist in capacity planning and estimating the treatment cost or source sharing decisions. In the literature, Markov chain models are generally applied for planning of inpatient services and modelling lengths of stay of patients for operations as Bhattacharjee and Ray (2014) states and exemplifies the papers. The McClean et al. (2007) study may be explained as a good example for Markov models in patient pathway. In this study, they made a Markov chain model which is utilized to extract patient pathways that are identified as the following stages that end up in the absorbing state. For the purpose of identifying the pathways, they developed branch and bound method based algorithm. The model is applied to geriatric patients in a London hospital and interesting pathways for geriatric patients which were found. The application of the Markov process on elective systems is relatively rare. However, Nunes et al. (2009) present one of the most successful papers in this field. They provide a decision model as a Markov decision process for admissions control of elective patient for different fields on a periodic base. For this aim, they produced and combined complex functions which are included in the model. In consequence, it is concluded that the model can create an optimum admission control plan which optimizes resources utilization while decreasing costs. Moreover, it is able to analyse the performance of various admission control strategies. Another noteworthy and different study is carried out by McClean et al. (2011). The uniqueness of this study is that they combine Discrete Event Simulation and Markov model for healthcare modelling. They purposed to present models for the stroke patient system which is fully integrated for community and hospital care. Therefore, they created a modelling framework which describes similar patient pathways with regard to factors like diagnosis, gender and age. Following this, they modelled the pathways and calculated distribution and times of Length of Stay (LOS) for multiple transient and absorbing states. Because of limitations of analytic approach, they buttress the framework with discrete event simulation and test different scenarios successfully. Therefore, it can be concluded that they developed analytic and simulation models considering the patients heterogeneousness and numerous care alternatives.

In literature, there are some good papers which develop optimization methods by applying with other techniques. Even if they do not use known or classical simulation techniques, they contribute literature on simulation in terms of giving new ideas to

simulation researchers for improving current simulation methods. One of the remarkable studies for this approach is carried out by Barbagallo et al. (2015) and in their study, they demonstrated the benefits of an integrated Business Process Modelling (BPM) and optimization approach, as a beneficial aid for the decision-making processes in the management of operating rooms. They use Business Process Modelling for characterizing as a general pathway to help significantly to modify theoretical ideas into practical application. This is because they argue that the Business Process Modelling method facilitate describing each of the procedures of each surgical situation. Their research methodology consists of three main steps. The first step is the detailed pathway definition. The secondly step is the resources, tasks, and times parameterization. The final step is the model optimization to improve OR schedules. As a result of this process and final simulation, it is found that operating theatre occupation may be increased by 10% to 20%.

As a conclusion, there are a great number of studies which use discrete event simulation models for different services in literature. Moreover, it is seen that different methods are used in addition to discrete event simulation methods in some studies. Especially, the studies which use optimisation and performance measuring techniques together with simulation which draw attention. On the other hand, good examples of other simulation methods are seen in the literature section although the number of these studies are not too much.

3.4. Gynaecology services Pathway modelling

Pathway modelling studies on Gynaecology services is comparatively limited. In particular, any study which focuses on elective pathway modelling in gynaecology service is not seen in the literature by applying the reviewing methodology that is explained in first part of the literature review section.

One of the most prospering paper was published by Lenin et al. (2015). They proposed to find the optimum duration between appointments and the number of nurses to decrease the patient's waiting time in the outpatient clinics of Obstetrics and Gynaecology Department at the University of Arkansas for Medical Sciences (UAMS). As usual in a discrete-event simulation method, a model was developed, validated, and some "what-if" scenarios were carried out to achieve the optimum durations between the appointments and the number of nurses. However, it is seen that

a different approach, which focuses on solving a schedule optimization problem by using optimization techniques, applied in "what-if" scenarios. Moreover, the staffs which include in US (ultrasound) or Lab technicians, nurses, doctors and check-in, check-out staff serving times are measured instead of measuring the stages on the patient pathway in this study, thus this can be stated as otherness of this study. Finally, they attained a noteworthy progress in the waiting time of patients in the clinic and they suggested some changes such as adding one more medical assistant and scheduling the morning appointments 16 minutes apart and the afternoon appointments 19 minutes apart for an optimum solution.

Najmuddin et.al (2010) carried out another good simulation study in the outpatient clinics of the gynaecology department. They aimed to examine the patient flow in the Obstetrics and Gynaecology Department (O&G Department) by making a simulation model which demonstrates the patient flow in the department. In addition to classic simulation approach, they used questionnaires to gather opinions and responds towards the department. Moreover, clearly explaining the methodology, simulation steps and what-if scenarios rises in the value of the study. As a result of the simulation model and what-if scenarios, they argue that long waiting time stems generally from the consultation room. Therefore, they suggested two improvements for this stage to decrease the patients' waiting time and to improve the service quality.

Griffin et al. (2011) carried out a study which can be defined as gynaecology service related simulation studies by modelling obstetric unit even if they do not focus on gynaecology service modelling. In addition to the classic aim of this kind of studies which is to find out bottlenecks in patient pathway and increase the efficiency of the system, scrutinizing the readiness of hospital for potential fluctuations in patient mix and patient volume is purposed in this study. After a usual simulation process and modelling steps, they claimed that path-based method is more unerring than a transition probability-based method to make a model for patient transitions between different units in the hospital.

Finally, Elkhuizen et al. (2007) published a paper on computer simulation for gynaecology and neurology outpatient departments. They aimed improving general applicable models to evaluate the appointment-based hospital facilities capacity. As well as a simple queuing model, a simulation model was utilized to analyse daily

variations in capacity and demand plans. After the modelling stage, they applied the model to gynaecology and neurology outpatient departments at the Academic Medical Centre in Amsterdam, the Netherlands. As a consequence, they found that extra capacity is needed for the neurology outpatient department to decrease the backlog and remain stable with a permanent capacity; nevertheless, the capacity is enough for the gynaecology department. Additionally, the same service level in the gynaecology department can be provided by using 14% less capacity as a result of the simulation. The importance of this study is that this paper is one of the relatively limited papers which focus on elective or appointment-based outpatient capacity.

In conclusion, based on the analysis of the literature it has been identified that there are some successful studies on general simulation usage in gynaecology services and they evaluate the general process of the service. However, it is seen that there is not a lot of remarkable studies which only focus on elective pathway modelling in gynaecology service in the literature. Therefore, this study may come into prominence.

4. METHODOLOGY

The methodology section which explains methods that are systematically applied in this study is organised based on previously published studies in similar subjects, discussions with project supervisors and considering prior knowledge. Due to the fact that determining and predicting demand for service at each stage and helping the service managers by analysing this demand are the main objectives of this study, this section consists of main two steps which are data analysis and simulation model. Because the data analysis step which also involves data mining and descriptive statistics process is the vital phase to determine the main demand features and building a correct model of the system. Therefore, data related works and outcomes are clarified in the first section and simulation related works is explained in the second section of the methodology.

4.1. Data Analysis

4.1.1. Data Source

The data which is used in this study is obtained from Information and Performance department in Cardiff and Vale University Health Board (CVUHB) by keeping patient information confidential. The main 6 datasets which are related with Gynaecology is utilised in this study. The datasets are called '*Referral', 'Out Patient waiting list', 'Out Patient Activity', 'Inpatient Waiting list', 'Inpatient* and *Diagnostic and Therapy (D&T)'.*

4.1.2. Data Period and Process

The data collection period is determined as 5 years, so the last 5 years of the data are gathered. However, the data period which is used in this study is decided as 18 months because of the difficulty of dealing with huge data and the danger of losing the details. Another problem to keep data duration very long such as 5 years is that possible changes which might affect the results can happen in patient pathways, treatment methods or patient demands and this can be the reason for the problem on model validation and verification. Therefore, all dataset are filtered between 01.01.2015 and 31.05.2016.

Data mining and analysing process require different kinds of qualifications on some computer software. Because of presenting different facilities, more than one computer

software is utilised in this study. Therefore, results that are obtained by a software are tested with another software and it becomes more accurate with a strong analysis. For this aim, R and R-Studio software are generally used for working between datasets such as merging, binding or matching data and datasets. Microsoft Office Excel is used for data producing and organising process in datasets and SPSS is used for some statistical analysis. In addition to this, distributions in the system are found by using @Risk software.

4.1.3. Descriptive Statistics

Describing the basic features of the data is the important and first step in a simulation model. Because it enables to evaluate the summary of the data and gives a clear idea about the main feature of the model. Moreover, descriptive statistics is compulsory to enter data into the simulation model. Therefore, descriptive analysis is used at the two main sections in this study. Firstly, data which is not directly used in the model is analysed because of its contribution to study in terms of evaluating demand. Secondly, data which is used in the simulation model is comprehensively analysed.

4.1.3.1. Analysing the model contributing data

One of the main objectives of this study is to understand the demand for the Gynaecology department. It is obvious that a lot of different factors is effective on demand, therefore understanding demand and factors which affect the demand contributes to increasing department capacity and quality. Due to this reason, data which provides information about demand is analysed. As a result of literature review and discussion with staff, it is seen that Did Not Attend (DNA) which is defined in section two is one of the most important factors to forecast demand in the short and the long time period. As Cumming (2005) mentioned, DNA accepted as a normal fact of hospital existence and strategies such as overbooking can be decided by analysing and understanding its reasons. Therefore, "Referral Status" data which includes "Attended" and "Did Not Attended" are analysed as a model contributing data. Results are explained, discussed and illustrated in appendix 1 in further detail.

4.1.3.2. Analysing data to be used in Simulation Model

Analysing data and attaining meaningful results is the crucial work in simulation related studies because the main simulation model is built based on this data. Due to

this reason, analysing data which is used in the model can be considered as the one of the most significant parts of this study. Therefore, whole data is analysed in depth and some interpretations which are related with analysis results are made to evaluate the results. Moreover, some distributions which are used in simulation and inform about the feature of the data are presented and the distribution types that fits the data are discussed. In addition to this, some supplementary data are produced by using data grouping, data transformation and data mining methods in the available dataset and these produced data are explained and analysed in this section. The results are presented according to data order in the simulation model. Furthermore, graphs and tables are utilised in order to show results clearly. Although the features of simulation and pathways are comprehensively explained in the simulation model section, mentioning the main characteristics of the model in this section briefly can be helpful to understand the results. Therefore, the model can be familiarised as follows; there are main three pathways which are Parent-gynaecology, Urodynamic and Gynae-Oncology pathway in the simulation model. Also, Parent-gynaecology pathway has two sub-pathways which are the Urgent pathway and the Routine pathway.

4.1.3.2.1. Analysing New-outpatient data

Firstly, new patient data are analysed as the entrance of the system. In referral dataset, there are 26,910 patients. The average of daily referred patient number is calculated as 69 patients by dividing the total patient number (26,910) to the total working day in 1.5 years (390). Therefore, the inter-arrival times of the system is calculated as 6.93 minutes by dividing the total working minutes in one day (480) to the average of the daily referred patient number (69).

The distribution of the new patients in terms of pathways is presented in Figure 1. It is clearly seen that the busiest pathway is the Parent-gynaecology pathway and 94.51% of new patients are treated in this treatment speciality clinics. Moreover, the 66.87% of outpatients who are in the Parent-gynaecology pathway are identified as urgent and follow the Urgent pathway, 33.13% of new outpatients in the Parent-gynaecology pathway follow the Routine pathway.

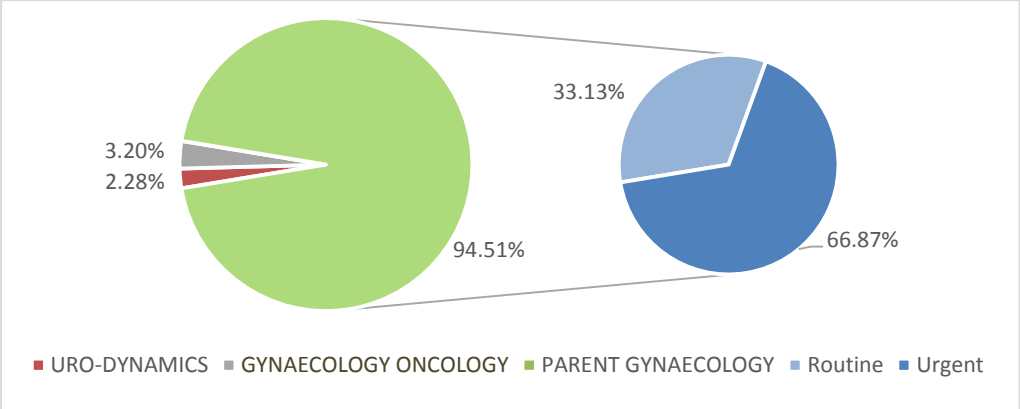


Figure 1 New Outpatients Distribution by Pathways

In the simulation model, a small pathway which is Urgent Suspected Cancer (USC) will be explained in detail. In brief, this pathway is between Urgent-parent-gynaecology and Gynae-Oncology pathways and it shows patients who are referred from parent-gynaecology to Gynae-Oncology service. So, investigating the ratio of urgent suspected cancer patients is seen as another important step to clearly identify demand on Gynae-Oncology service.

As it is seen in Figure 2, 7.57% of patients are Cancer Suspected and directed to Gynae-Oncology service and 92.43% of patients continue their pathways in Parent-gynaecology.

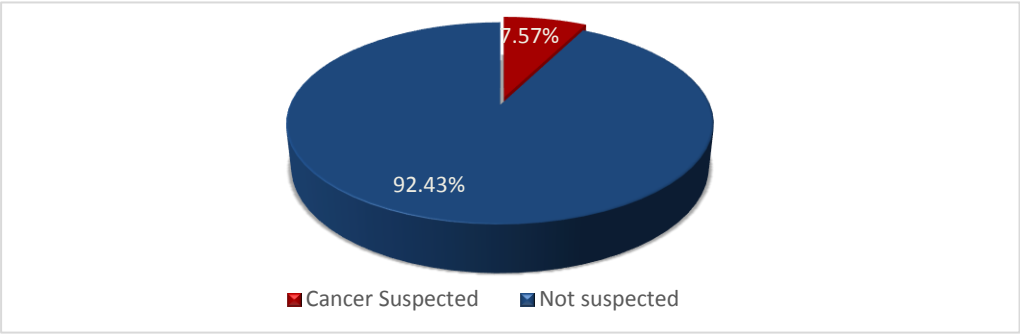


Figure 2 Distribution of Urgent Cancer Suspected data

After first treatment, patients are directed to different sub-pathways according to the treatment outcomes which are identified in the data set as “admin outcome”. However, some of the data which are in the “admin outcome” dataset is identified and grouped to have the most suitable and meaningful groups. This is because it is noticed that the patient who are recorded as “admitted as emergency”, “attended no outcome”, “follow-up appointment booked”, “partially booked” , “query follow-up” and “suspended-awaiting results” visit the hospital at the next step. Therefore these

outcomes are grouped as “FOLLOW-UP GROUP". Similarly, patients who are recorded as “DNA, no outcome” and “transferred to another H\C professional” are grouped in “OTHER” group and the patients who are recorded as “placed on inpatient W\L (with date)” and “placed on inpatient W\L (without date)” are gathered in “INPATIENT” group. The important point is that if a patient who is DNA (Did not attend) just once, he or she can receive another appointment to continue follow-up treatment. So, DNA’s are divided into two subgroup as “DNA cont.” which includes inpatients who continue follow-up treatment and “DNA, no outcome” which consists of patients who have disappeared. Following this, “DNA cont.” group is placed in the “FOLLOW-UP GROUP" and “DNA, no outcome” is placed in the “OTHER” group. The distribution of the first treatment ‘grouped’ outcomes for each pathway are shown in Figure 3. Additionally, the same distribution for each Parent-gynaecology pathways are presented in Figure 4.

It is seen in Figure 3 that patients are mostly directed to follow-up appointments in all pathways as a result of the first treatment. However, it is remarkable that the inpatient rate is considerably high in the Gynae-Oncology pathway with 30.4% when compared with others. Moreover, the highest discharging rate is seen in Parent-gynaecology with 21.9% and the highest ‘other’ group is in the Urodynamic pathway with 14.8%.

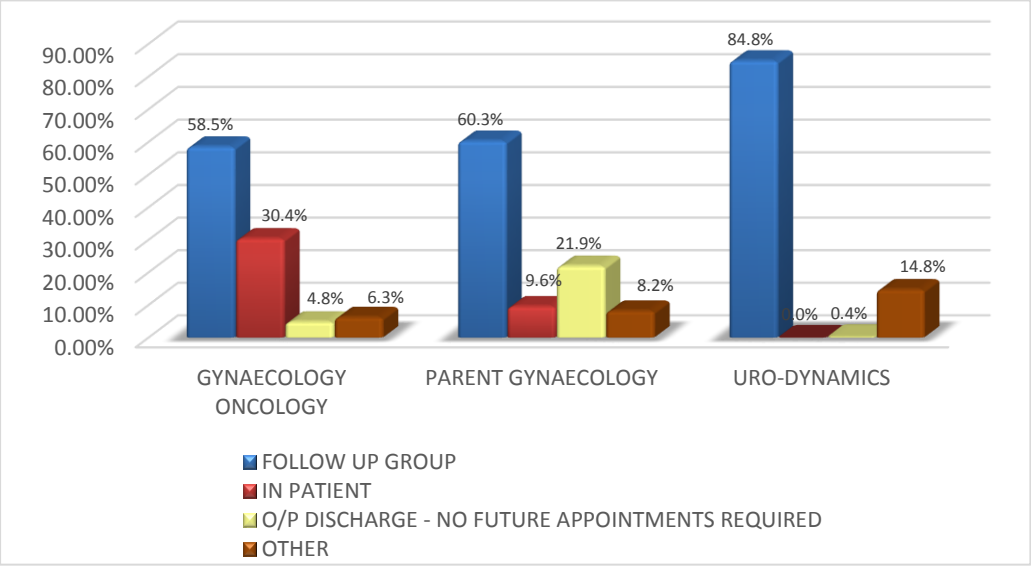


Figure 3 First treatment grouped outcomes by pathways

Similar to Figure 3, follow-up appointments have the highest ratio in the first treatment results for both Routine and Urgent pathways in Figure 4. Moreover, it is seen that the inpatient rates of Parent-gynaecology sub-pathways are quite similar. However, the discharging rate and the ‘other’ rate of Routine pathway are more than the Urgent

pathway. Especially, the patients who are in the Routine pathway are more prone to disappear with 15.3%.

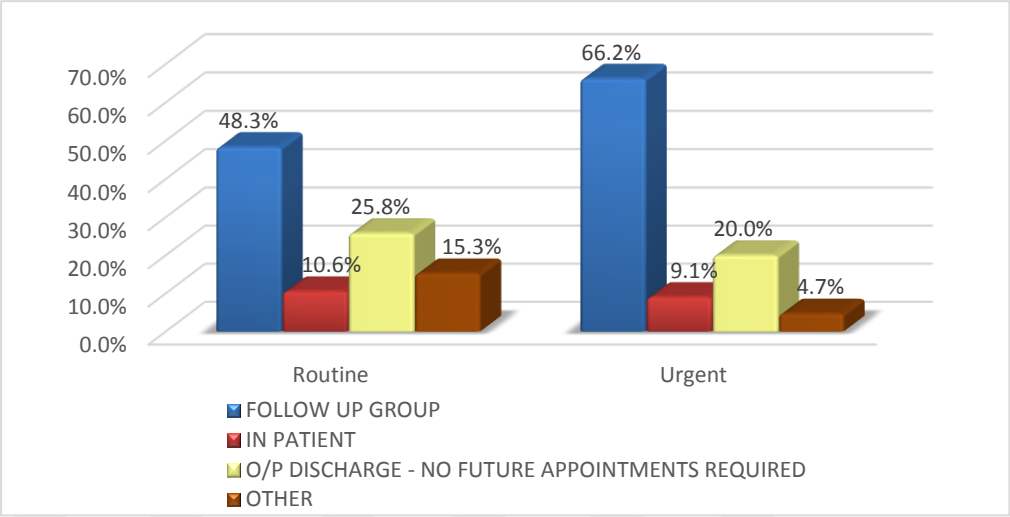


Figure 4 First treatment outcomes by Parent-gynaecology Sub-pathways

4.1.3.2.2. Analysing Follow-up appointment data

It is obvious that if a follow-up appointment decision is made as an outcome of the first treatment appointment, the time period between the first outpatient treatment appointment and the next follow-up appointment will be different for patients because of the reasons such as treatment methods, kind of illnesses and patient characteristics. Therefore, one of the important data analysis is done to discover the follow-up time period distribution. For this aim, some data producing and grouping processes are performed in the dataset. Firstly, the duration between appointments as day, week and month are calculated. According to the information which is attained from the Gynaecology service manager, appointment duration data is grouped as “less than 1 month”, “between 1-3 months”, “between 3-6 months”, “between 6-9 months”, “between 9-12 months” and “more than 12 months”. Also, patients who do not have another follow-up appointment are identified as “discharged or others” in another group, so they could be eliminated from the dataset. Another important identification in this data set is made for patients who entered the Gynaecology department system before 01.01.2015 who are still in the system but the time of their previous appointment is not known because of the time period of the study. For this reason, these patients are recoded and grouped as 0 in this dataset.

Follow up time periods	GYNAE-ONCOLOGY	PARENT GYNAECOLOGY	URODYNAMIC	Grand Total
Less than 1 month	74.85%	55.72%	23.91%	55.98%
Between 1-3 months	17.96%	17.15%	46.38%	17.73%
Between 3-6 months	5.99%	16.00%	22.46%	15.68%
Between 6-9 months	0.90%	9.68%	5.80%	9.22%
Between 9-12 months	0.00%	0.87%	0.72%	0.82%
More than 12 months	0.30%	0.58%	0.72%	0.57%
Total	100.00%	100.00%	100.00%	100.00%

Table 1 New outpatient first follow-up time periods by Gynaecology Pathways

It can be said by looking at Table 1 that three-quarter of the Gynae-Oncology patients wait 'less than 1 month' for the first outpatient follow-up appointment and it is also remarkable that there are nearly no patients who wait more than '6 or 9 months' in this pathway. Although the Parent-gynaecology pathway has the similar first outpatient's follow-up appointment time period distribution with Gynae-Oncology pathway, the ratio between time periods are different and it is important that the ratio of the patients who wait 'between 1 and 3 months' and 'between 3 and 6 months' are quite close. However, this first follow-up appointment distribution in Urodynamic pathway changes a bit compared with other pathways. Most (46.38%) of the Urodynamic patients wait 'between 1 and 3 months' for their first follow-up appointment and this patient rate is equal to the sum of the rates of patients who wait 'less than 1 month' (23.91%) and 'between 3 and 6 months' (22.46%).

The same analysis is done for Parent-gynaecology sub-pathways and the result is illustrated in Figure 5. As it is expected, most (69.5%) of the urgent patients wait less than 1 month for their first follow-up appointment whilst most (35.4%) of the Routine patients wait between 3 and 6 months. Furthermore, the percentage of the urgent patients who wait 'between 1 and 3 months', 'between 3 and 6 months' and 'between 6 and 9 months' are nearly identical but the Routine patient distribution in the same time periods are changeable.

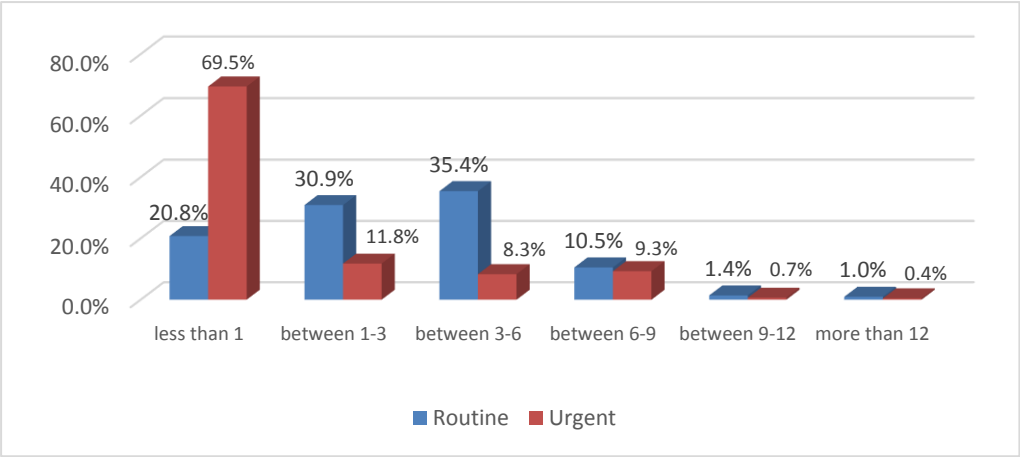


Figure 5 New outpatient first follow up time periods by Parent-gynaecology sub-pathways

As it happens after the first (new) outpatient appointment, patients are directed to different directions according to their follow-up appointment outcomes which are identified and grouped before as "grouped admin outcome". The distribution of the follow-up appointment outcomes by pathways is shown in Figure 6.

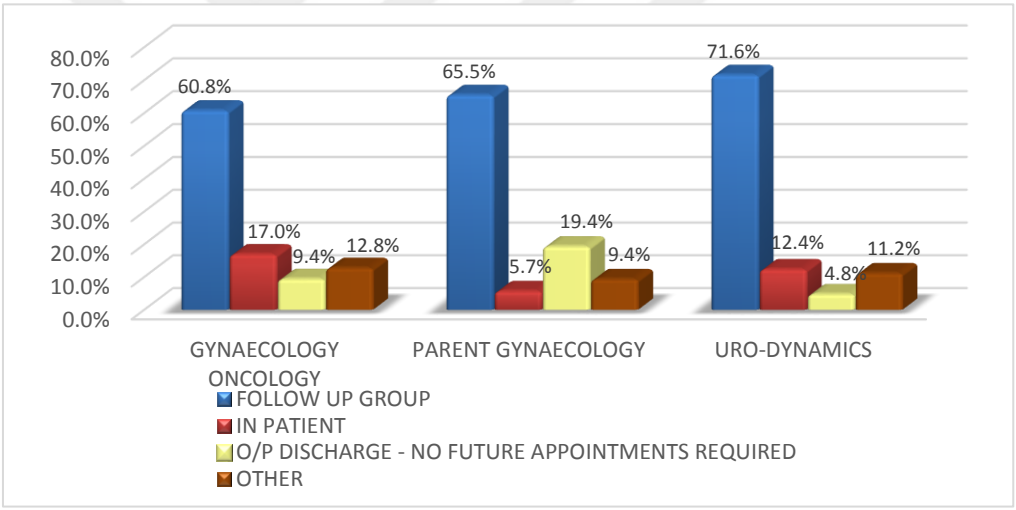


Figure 6 Follow up appointment outcomes by pathways

Similar to the first treatment outcomes, patients are mostly directed to follow-up appointments in all pathways as a result of the follow-up appointment and the inpatient rate is higher than others in the Gynae-Oncology pathway with 17%. Furthermore, the highest discharging rate is again seen in the Parent-gynaecology with 19.4%. However, the most important difference between the first and follow-up appointment outcomes is seen at the ratio of "other group". Though 'other group' rates of each pathway close, the highest 'other group' rate is in the Gynae-Oncology pathway with 12.8%.

As usual in this part, the same analysis is done for Parent-gynaecology pathways and the results are illustrated in Figure 7. Alike the previous figure, most of the follow-up patients in both pathways continue their pathways with another follow-up appointment according to the follow-up appointment outcomes.

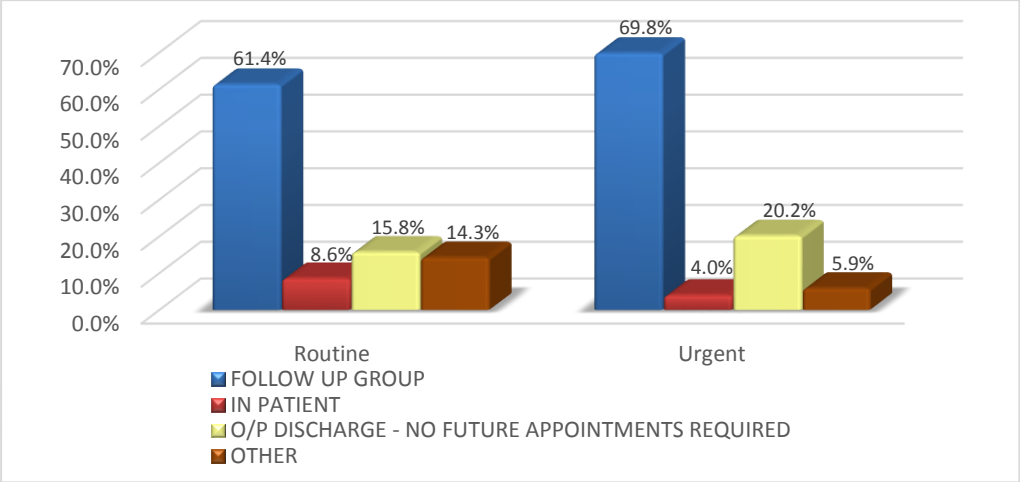


Figure 7 Follow up appointment outcomes by Parent-gynaecology sub-pathways

The second highest ratio at the follow-up appointment outcome of the parent-gynaecology sub-pathways is found in the discharge rate but the discharge rate of the Urgent pathway is more than the Routine pathway's. Additionally, inpatient and the 'other' ratios of Routine patients' follow-up appointment outcomes are higher than inpatient and the other ratios of Urgent follow-up appointment outcomes.

One of the significant steps in the model is to identify the follow-up appointment outcomes or decisions by eliminating patients who continue their pathway with another follow-up appointments. Hence, this step is shortly called as "what, if it is not Follow-up stage" in the simulation. In fact, this is not a separate analysis which is done on the previous analysis but excluding follow-ups gives the opportunity to found out directions clearly and to compare pathways, effortlessly.

As it is seen in Figure 8, nearly half of the Gynae-Oncology and the Urodynamic pathway follow-up patients who do not have another follow-up appointment are directed to inpatient treatment. But, the ratio of inpatient treatment of parent-gynaecology is quite low. More than half (56.2%) of the parent-gynaecology pathway follow-up patients who do not have another follow-up appointment are discharged. When compared with other pathways, this discharge rate is found as the highest discharge rate. Another noteworthy result is that the ratio of the follow-up appointment outcomes which are described as 'other' is quite similar and stable for each pathway.

This group also includes inpatient who “Did not attend” more than once to their appointment.

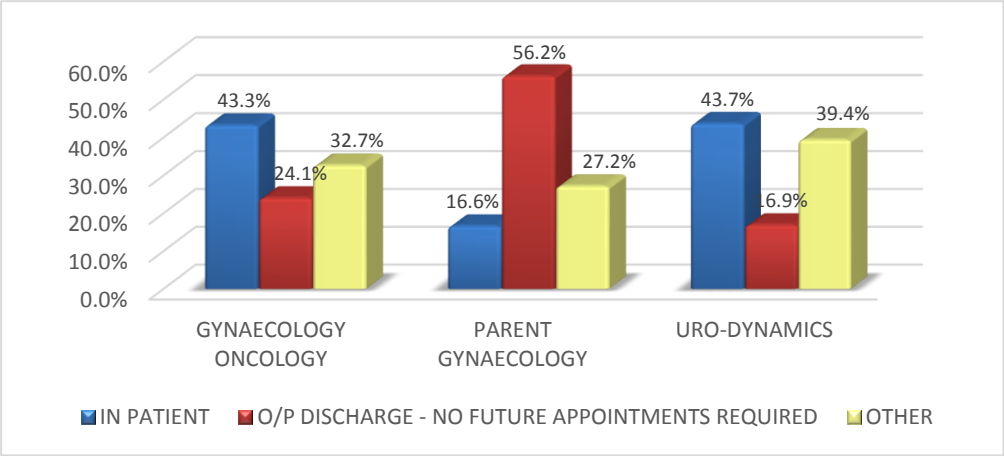


Figure 8 Eliminated Follow up appointment outcomes by pathways

The eliminated-follow-up appointment outcome analysis for the Parent-gynaecology Sub-pathways is done for the same aim with the former analysis and the result is presented in Figure 9.

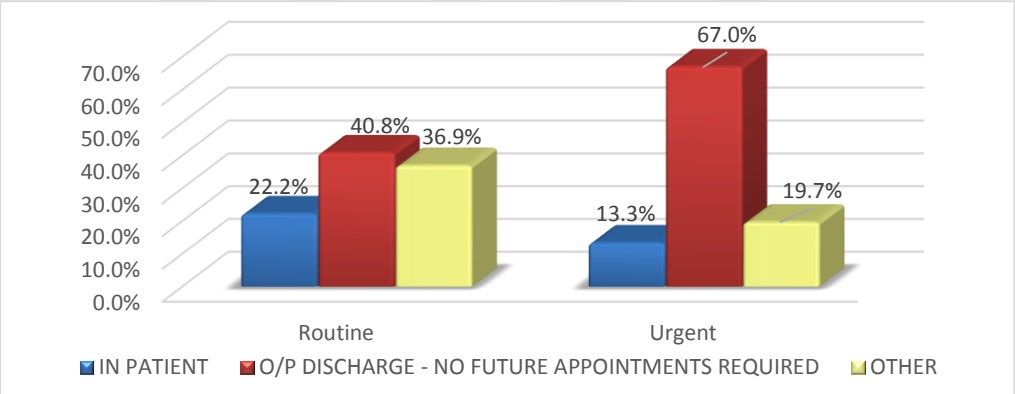


Figure 9 Eliminated Follow up appointment outcomes by Parent-gynaecology Sub-pathways

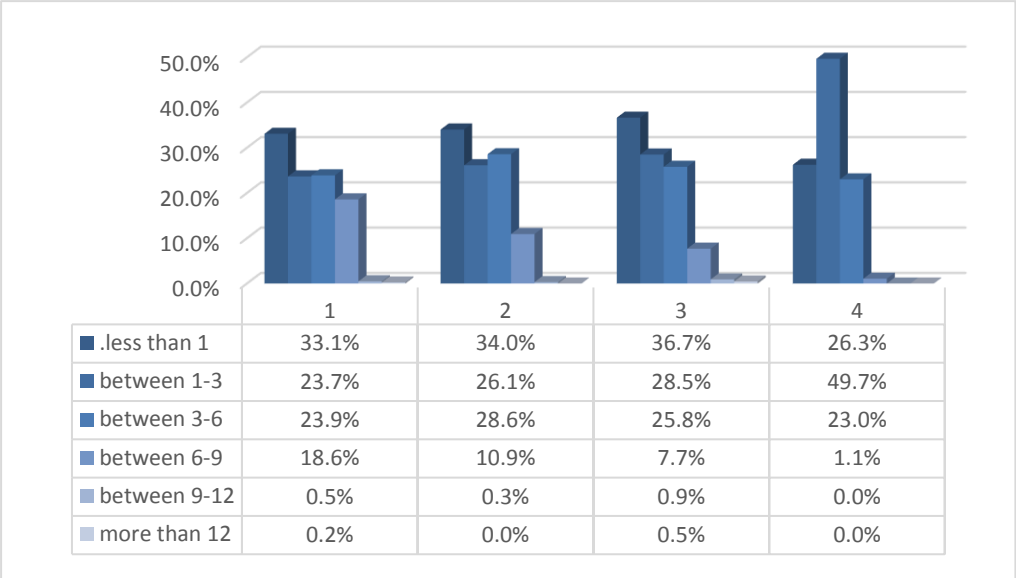
According to Figure 9, the discharge rate of the Urgent follow-up-patient who do not have another follow-up appointment which is 67% is more than the discharge rate of the Routine one. However, the ‘other’ and the ‘inpatient’ rates of the Routine follow-up patients are more than the ‘other’ and the ‘inpatient ‘rates of the Urgent follow-up-patient.

One of the most important and powerful characteristics of the model which is built in this study is that the relationship between the follow-up appointments periods and the follow-up appointment numbers can be found out. Finding out the patient distributions of the follow-up appointment time periods by the follow-up appointment numbers for all Gynaecology pathways is one of the most significant analyses of this part. For this

analysis, again some data producing and grouping processes is applied. Firstly, the follow-up-number or the hospital visiting count is found for each patient. However, making some corrections are needed in this produced data. This is because there are backlogs which represent patients who are already in the system but the number of their previous follow-up appointments are not known because of the time period of study. Therefore, these backlogs are defined as 0 in the follow-up appointment number data set and patients who have not had any follow-up appointments yet are coded as new. Consequently, follow-up appointment numbers (also known as hospital visiting numbers) are coded as 0, new, 1, 2, 3 etc. After finding the patients' follow-up appointment numbers, the distribution of the follow-up appointment time periods by the follow-up appointment numbers for each pathway is attained and the results are provided as tables in appendix 2. According to the results, the more than 80% of total patients are discharged at the first, second or third appointments. So, the follow-up appointments which are equal and more than four are gathered in a group to see the main frame. Consequently, the patient's follow-up appointment numbers which are analysed in the model consist of the first follow-up appointment, second follow-up appointment, third follow-up appointment and 'more than four' follow-up appointments.

Figure 10 illustrates the distribution of the follow-up appointment time periods against the follow-up appointment numbers for the Gynae-Oncology pathway. This figure and the following charts should be clarified to read correctly; the distribution of the waiting time periods explain the time that will be waited after the designated follow-up appointment number. In other words, this figure can be read as such e.g. 33.1% of Gynae-Oncology patients who attended their first follow-up appointment will wait less than 1 month for the next follow-up appointment. So, in the light of this information, some significant inferences can be made. It is a noteworthy point that nearly all Gynae-Oncology patients will wait less than 9 months for their next follow-up appointment. Moreover, most of the patients wait less than 1 month for the next follow-up appointment after their first, second and third appointment while nearly half of the patients who attended their fourth or more follow-up appointment will wait between 1 and 3 months for their next follow-up appointment. Additionally, it can be said that

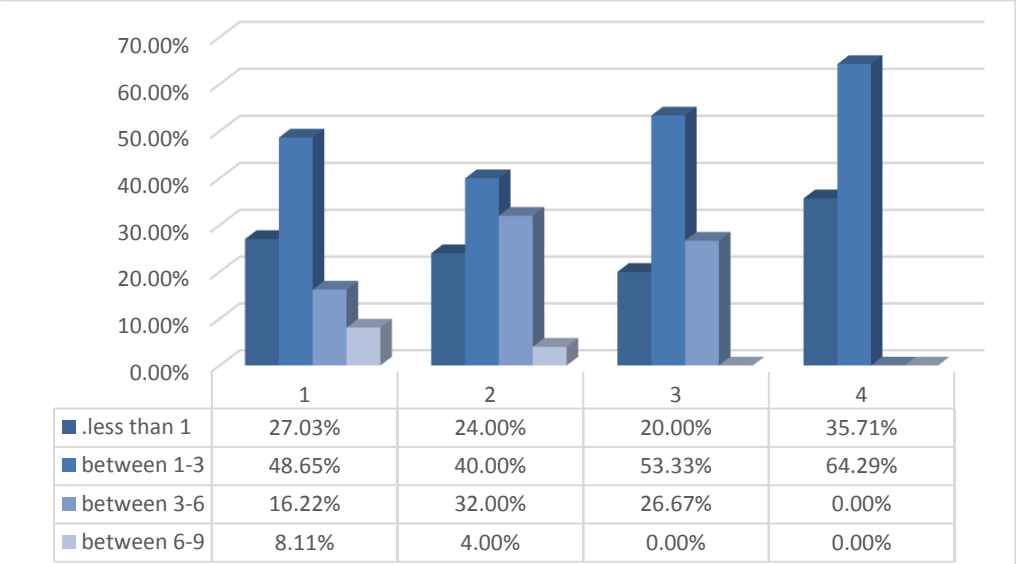
the follow-up time period distribution of the first and second follow-up appointment are similar.



	1	2	3	4
.less than 1	33.1%	34.0%	36.7%	26.3%
between 1-3	23.7%	26.1%	28.5%	49.7%
between 3-6	23.9%	28.6%	25.8%	23.0%
between 6-9	18.6%	10.9%	7.7%	1.1%
between 9-12	0.5%	0.3%	0.9%	0.0%
more than 12	0.2%	0.0%	0.5%	0.0%

Figure 10 Distribution of follow up time periods against follow up numbers for Gynaecology Oncology Pathway

The same analysis which is applied for the Gynae-Oncology pathway above is done for Urodynamic pathway and results presented in Figure 11.

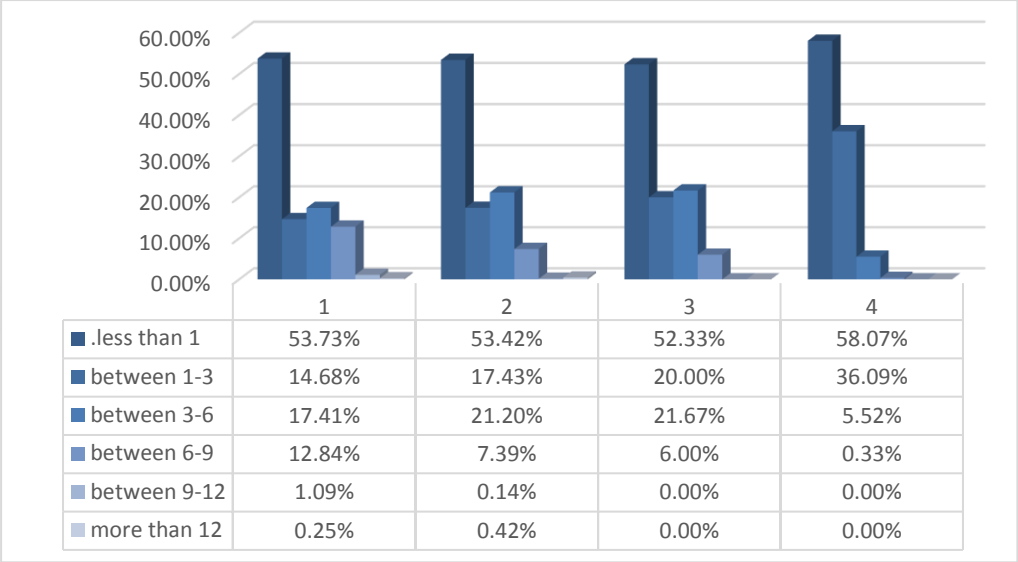


	1	2	3	4
.less than 1	27.03%	24.00%	20.00%	35.71%
between 1-3	48.65%	40.00%	53.33%	64.29%
between 3-6	16.22%	32.00%	26.67%	0.00%
between 6-9	8.11%	4.00%	0.00%	0.00%

Figure 11 Distribution of follow up time periods against follow up numbers for Urodynamic Pathway

It is seen that there is no patient who waits more than 9 months for their next follow-up appointment and most of the patients wait for the next follow-up appointment between 1 and 3 months after any follow-up appointment in the Urodynamic pathway. Moreover, the follow-up time period distribution shape of the second and third follow-up appointments look alike even if the percentages are different.

Instead of finding the follow-up-appointment time periods against follow-up-appointment numbers for Parent-gynaecology pathway, investigating this for Urgent and Routine pathways is more logical and useful for the model. Therefore, the same analysis which is done for other main pathways is done for these two sub-pathways. Firstly, this processes applied for Urgent parent-gynaecology pathway and results are presented in Figure 12.

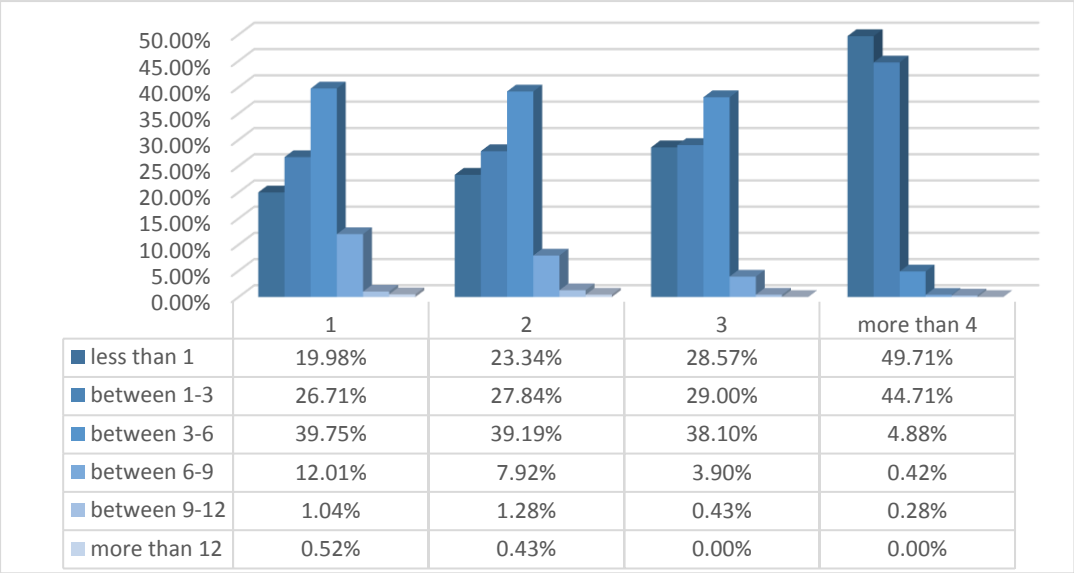


	1	2	3	4
.less than 1	53.73%	53.42%	52.33%	58.07%
between 1-3	14.68%	17.43%	20.00%	36.09%
between 3-6	17.41%	21.20%	21.67%	5.52%
between 6-9	12.84%	7.39%	6.00%	0.33%
between 9-12	1.09%	0.14%	0.00%	0.00%
more than 12	0.25%	0.42%	0.00%	0.00%

Figure 12 Distribution of follow up time periods against follow up numbers for Urgent Pathway

As can be expected, more than half of Urgent pathway patients wait less than 1 month for their next follow-up appointment after any previous follow-up appointments and also there is nearly no patient who wait more than 9 months for their next follow-up appointment. Moreover, distribution of waiting times after first three appointments are quite similar. Another important point is that the patients who wait between 1 and 3 months after their first, second and/or third follow-up appointments have the second highest percentage in these distributions.

The final analysis of follow-up time periods against follow-up numbers is performed for Routine parent-gynaecology pathway and outcomes can be found in Figure 13. Similar to Urgent pathway, nearly all patients wait less than 9 months for their next follow-up appointment. However, the main difference between Routine and Urgent pathways is that most of the patients wait between 3 and 6 months after their first, second and/or third follow-up appointments for the next appointment. Again, distribution of waiting times after first three appointments are shown similarity. Also, it is noteworthy that almost all patients who attended their ‘4 or more’ follow-up appointment wait less than 3 months for their next follow-up appointment.



	1	2	3	more than 4
less than 1	19.98%	23.34%	28.57%	49.71%
between 1-3	26.71%	27.84%	29.00%	44.71%
between 3-6	39.75%	39.19%	38.10%	4.88%
between 6-9	12.01%	7.92%	3.90%	0.42%
between 9-12	1.04%	1.28%	0.43%	0.28%
more than 12	0.52%	0.43%	0.00%	0.00%

Figure 13 Distribution of follow up time periods against follow up numbers for Routine Pathway

Consequently, Urgent and Routine pathway results show the contrast in terms of distribution of waiting time periods for follow-up appointments. So, in the light of these results, it can be deduced that analyses which are made in this section are consistent and accurate.

4.1.3.2.3. Analysing Inpatient data

In addition to the new outpatient, follow-up outpatient treatment steps, there is another treatment step which is inpatient treatment in the Gynaecology department. Therefore, some analyses which are related to inpatient treatment should be performed to complete the model. It is apparent that patients who are treated in inpatient services continue their pathways with at least one follow-up appointment. However, the distribution of the inpatient follow-up time periods which define the waiting time of patients between discharging inpatient treatment and first inpatient follow-up appointment differs with the distribution of outpatient's first follow-up time periods which is previously explained in Table 1. The distribution of inpatient follow-up time periods by Gynaecology pathways is presented in Table 2. The same data mining and grouping process which is performed to find the distribution of outpatient-first follow-up time periods are used for this distribution as well.

Follow up time periods	GYNAE-ONCOLOGY	PARENT GYNAECOLOGY	URODYNAMIC	Grand Total
Less than 1 month	62,66%	38,76%	41,18%	47,98%
Between 1-3 months	32,73%	25,60%	17,65%	28,27%
Between 3-6 months	3,08%	19,29%	35,29%	13,19%
Between 6-9 months	1,26%	10,76%	0,00%	7,00%
Between 9-12 months	0,28%	4,44%	5,88%	2,85%
More than 12 months	0	0,01%	0	0,007%
Total	100.00%	100.00%	100.00%	100.00%

Table 2 Inpatients follow-up time periods by Gynaecology Pathways

It is seen in table 2 that most (62.66%) of Gynae-Oncology pathway patients wait less than 1 month for the first inpatient follow-up appointment and only less than 5 percent of patients wait more than 3 months for the first inpatient follow-up appointment. Parent-gynaecology pathway has a decreasing trend in inpatient follow-up time periods and it can be said that as the waiting time increases, the distribution of patients decreases. The inpatient follow-up appointment distribution in the Urodynamic pathway is quite changeable when compared with other pathways. Most (41.18%) of the patients who are in Urodynamic pathway wait less than 1 month for their first inpatient follow-up appointments. Also, it is seen that the rate of Urodynamic patients who wait between 3 and 6 months is quite high when compared with other pathways.

Again, the same analysis is done for Parent-gynaecology pathways and the results are illustrated in Figure 14. As it is expected, most (62.2%) of the urgent patients wait less than 1 month for their first inpatient follow-up appointment while most (33.6%) of the Routine patients wait between 1 and 3 months. Furthermore, it is seen that there is a clear decreasing trend in the distribution of the inpatient follow-up time period. Also, it can be mentioned to a similar trend for the inpatient follow-up appointment distribution of the Routine parent-gynaecology pathway when the less than 1-month column is excluded from the chart.

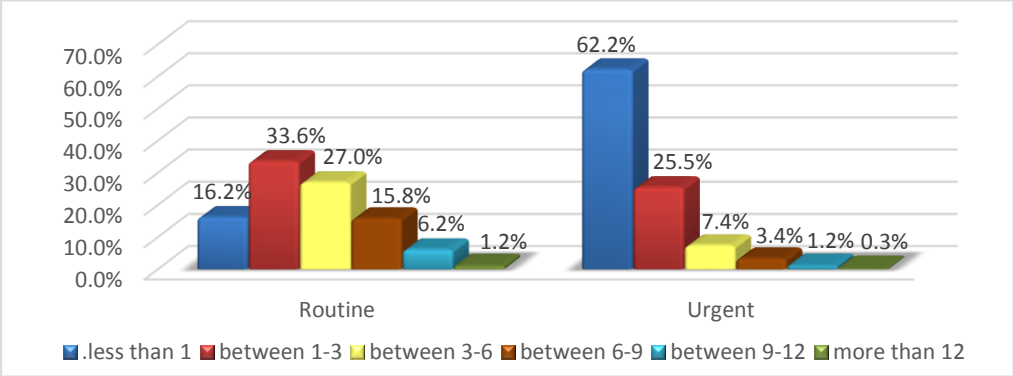


Figure 14 Inpatient first follow up time periods by Parent-gynaecology sub-pathways

One of the most important issues at the inpatient treatment is to analyse the 'length of stay' (LOS) which describe how many nights patients stayed in the hospital. It is obvious that the bed capacity and the bed utilisation is directly connected with the 'length of stay' and the bed capacity and utilisation strategies are mostly determined by analysing the 'length of stay' data. Moreover, the 'length of stay' is one of the most effective factors on inpatient waiting times. Therefore, the 'length of stay' data of each Gynaecology pathway is analysed. Firstly, the percentage of the day case inpatient treatments which explain the procedures that patients do not need to stay the night in hospital are examined and results are presented in Figure 15.

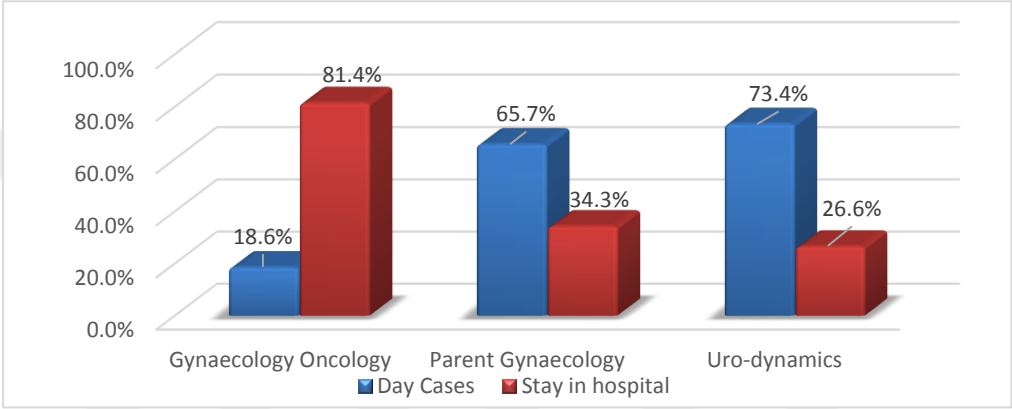


Figure 15 The percentage of Day Cases by Pathways

According to Figure 15, the highest percentage of the day cases with 73.4% is seen in the Urodynamic pathway while the lowest percentage with 18.6% is seen in the Gynae-Oncology pathway. Moreover, Parent-gynaecology and Urodynamic pathways show similar features in terms of having more day case procedures than procedures which require stay in hospital though their percentages are not exactly same.

At the second step of the analysing 'length of stay data', day cases are eliminated from the dataset and the distribution for the rest of the data which only includes the number of days that the patient stayed in hospital is found. For this aim, @RISK 7 software is utilised and the results are presented in Table 3. In addition, the screenshots of the @RISK 7 outcomes are illustrated in Figure 16 as a summary. However, the big screenshots of the @RISK 7 outcomes can be found in the appendix 2.

Inpatient LOS	Gynae-Oncology	Parent Gynaecology	Urodynamic
Fitted Distribution	Exponential distribution	Exponential distribution	Exponential distribution
Average days	3,25	1,86	1,88
Hours (converted)	26	14,88	15,04
Minutes(converted)	1560	892,8	902,4

Table 3 Results of Length of stay data

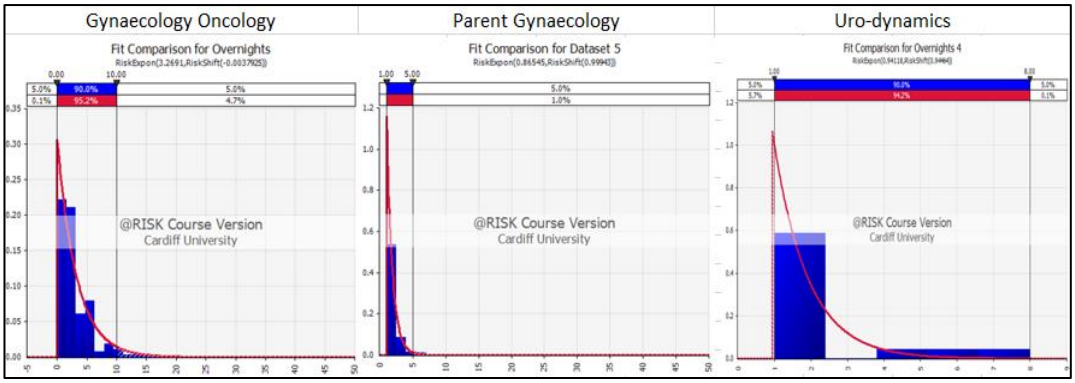


Figure 16 Screenshots of @Risk 7 outcomes

According to the @RISK 7 results , the days which the patients stay in hospital fit the Exponential distribution for all gynaecology pathways, though the average length of stays are different. Gynae-Oncology patients stay in the average of 3.25 days, Parent-gynaecology patients stay for 1.86 days and Urodynamic patients stay for 1.88 days. However, it should be stated that the Length of stay analysis for the Urodynamic pathway is made by using very limited data. Nevertheless, it is expected to have similar attributes with Parent-gynaecology pathways so it can be said that the results meet the expectations and show consistency.

4.1.3.2.4. Analysing D&T data

In addition to the main treatment process, scanning or test can be required for some patients. Therefore, patients who need scanning or test are referred to Diagnostic and Therapy (D&T) or Radiology services which are shortly called D&T and they turn back to the Gynaecology department with results. Due to possible effects of this stage on the model in terms of affecting the clinic demand or waiting durations for treatment, another data analysis is made to find out the percentage of gynaecology patients who visit the D&T services. The percentages of total number of D&T visits by Gynaecology pathway is presented in Table 4.

D&T Visiting number	GYNAE-ONCOLOGY	Routine PARENT GYNAECOLOGY	Urgent PARENT GYNAECOLOGY	URODYNAMIC
0	41.62%	82.14%	79.49%	8.98%
1	19.74%	13.86%	14.39%	73.25%
2	21.73%	3.05%	3.89%	13.57%
3	8.24%	0.73%	1.44%	2.20%
4	3.98%	0.16%	0.46%	1.80%
5	2.84%	0.04%	0.22%	0.00%
6	0.85%	0.01%	0.11%	0.00%
7	0.57%	0.00%	0.00%	0.00%
8	0.28%	0.00%	0.00%	0.20%
9	0.14%	0.00%	0.00%	0.00%

Table 4 Distribution of D&T visits

It is seen that 41.62% of Gynae-Oncology patients, 82.14% of Routine-parent-gynaecology patients, 79.49% of Urgent-parent-gynaecology patients and 8.98% of urodynamic patients do not visit D&T services in any stage of their patient pathways. It is remarkable that 73.25% of urodynamic patients visit D&T once only in their pathways. Also, the ratio of the Gynae-Oncology patients who visit the D&T twice is higher than visiting once. Another significant point is that the highest D&T visiting rate of Routine and Urgent parent-gynaecology patients who visit D&T are seen in visit one time. Furthermore, the biggest number of D&T visits is seen in the Gynae-Oncology pathway with 9 times.

4.1.3.2.5. Analysing Clinic Schedules

The final data analysis step is carried out to determine the number of clinics which run in a day and find out the weekly clinic schedule. The total of 77 clinics have served in the Gynaecology department in 18 months. However, when looked in detail, it is seen that some clinics are used just in specific time periods such as the first or the last 4 months or a few times in all the time periods. So, the rarely used clinics are eliminated to have the core data at the first step. After most used clinics are selected and grouped, 8 weeks which are able to represent features of different seasons are randomly selected. Maximum, minimum and average of running clinic counts are calculated for each day of the week by analysing the 8 weeks data. In addition, the maximum and minimum number of running clinics for each pathway are found. Following this, the clinics are distributed as new and follow-up or busy and not busy appointments and weekly clinic schedules could be prepared for 'Urgent-New Patient Parent-gynaecology', 'Urgent-Follow-up Parent-gynaecology', 'Routine-New Patient Parent-gynaecology', 'Routine-Follow-up Parent-gynaecology', 'Urodynamic' and 'Gynaecology-oncology' pathways. It is important that there are no clinics which serve to only follow-up or new patients in the real system. However, the dividing and distributing process presents better results to understand the system and will help to generate scenarios.

The distributing process is applied proportionally based on the expected clinic count which is calculated by measuring weekly demand on service and workload on follow-up appointment time periods. An example can help to explain the process as follows; for Urgent pathway, the count of the total of new patients of this pathway is found as

16,694 by using the new outpatient distributions which are previously revealed and the average of daily new patient demand for this pathway is calculated as 42. Finally, the number of weekly running clinics meets the Urgent-new patient demand is found out as 1.783 by dividing the total service minute (853) by working minutes in a day (480). Following this, the clinics are distributed in days based on the maximum number of running clinics and the weekly average of running clinics is found as 1.8 which is very close to the real average. However, it is important that some corrections are made in the relevant dataset. For example, in the data set, a clinic runs one hour in a day and it looks 15 patients. It is understood that the clinic runs at least three hours but the data is entered as 1 hour. Therefore, this clinic is considered as a clinic which runs 4 hours. Consequently, the clinic schedule is created according to this kind of modifications. The final big timetable which is made and used in the simulation can be seen in Table 5.

Days	Pathway	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00
Monday	Urgent	9	4	4	3	8	7	7	1
	Routine	4	2	2	1	2	2	2	0
	Gynaecology	0	0	0	0	0	0	0	0
	Urodynamic	0	0	0	0	0	0	0	0
Tuesday	Urgent	8	7	4	3	5	4	4	1
	Routine	4	2	2	1	2	2	1	0
	Gynaecology	2	1	1	0	2	1	1	0
	Urodynamic	2	2	2	0	0	0	0	0
Wednesday	Urgent	9	4	4	1	7	5	4	1
	Routine	4	2	2	1	2	2	1	1
	Gynaecology	2	3	1	0	3	2	3	2
	Urodynamic	2	1	0	0	0	0	0	0
Thursday	Urgent	10	9	7	1	8	7	7	1
	Routine	4	2	2	1	2	2	2	1
	Gynaecology	2	2	1	0	2	2	0	1
	Urodynamic	2	1	0	0	0	0	0	0
Friday	Urgent	8	7	4	1	8	6	4	0
	Routine	4	2	2	1	2	2	1	1
	Gynaecology	0	0	0	0	0	0	0	0
	Urodynamic	0	0	0	0	0	0	0	0

Table 5 Clinic Schedule (Average)

4.2. Simulation Model

4.2.1. Simulation Software and Process

In this study, the Simul8 (version 23.0) software which is widely used in healthcare modelling is used to build the Gynaecology department patient pathway model. The simul8 software can be defined as a user-friendly process based Discrete Event Simulation tool. This software entities flow through the system with conditions, which determine the next route of entities, in the specified duration.

Usual modelling process which is used throughout most of the relevant literature is followed in this study. This process consists of 6 main steps which are 'system definition', 'data collection and analysis', 'model development', 'verification and validation', 'experiments or scenarios' and 'analysing and interpreting results'. Moreover, this process includes some iterative steps especially between data analysis, model development and verification-validation phases. Because the model is developed according to the verification-validation and the developing model sometimes requires more data analysis. As a result of the data analysis, the model is developed and its verification-validation is investigated again. This iterative process continues until the validated and verified model is built. Therefore, step by step development of the model can be found in appendix 3.

4.2.2. Simulation Objects

There are five main simulation objects which are start points, queues, activities, resources and endpoints. Additionally, there are other important elements such as work items, route arrows, clock, labels and distributions in a simulation. In this part, all objects and elements are defined and their usage in the model is explained to reveal all units in the system, before evaluating the overall model construction.

- Start points

  Start point is where work items (patients) arrive in the system. In this model, there is only one start point and patients who are referred to the Gynaecology pathway enter the system from this point. Therefore, the start point is called the "*Referred Patients*" in the model. As it is explained in the data analyse section, the inter-arrival time is stated an average of 6.93 minutes.

- Queues

  A queue is defined as a place where work items are held while they are waiting for the next process. However, unlike the industry or some kind of healthcare models, work items (patients) do not wait in a physical room or physical queue in elective pathways. Therefore, patient waiting lists are considered as queues in this model. Because of this reason, a queue is set for each treatment activity and the total 58 queues are used in the model. Moreover, minimum waiting times are provided for the follow-up appointment queues which patients have to wait a predetermined duration. In addition, start-up which means queue at

the start of the model run is defined as backlogs for the first outpatient appointment queues.

- Activities

  An activity or work centre is described as a place where work is performed by a resource. Due to the fact that this study is a healthcare modelling, patients are seen or treated at activities in the model. However, the model also includes some dummy activities which are directed patients to activities or queues without actually holding the patients for any time in the activity. Dummy activities help to build patient pathway models, so they do not actually exist in the real process. Therefore, fixed distribution is used and fixed value which identify the activity time is set as zero for dummy activities.

  In the model, there are 38 activities (work centres) and 74 dummy activities. However, some of activities and dummy activities can be grouped according to their mission in the model. Because the model consists of 4 main pathways which have the identical steps and processes. For example, there are four `*less than 1 month*` activities which are `*less than 1 month_URO*`(for Urodynamics), `*less than 1 month_PG_R*`(for Routine Parent-gynaecology), `*less than 1 month_PG_U*`(for Urgent Parent-gynaecology), `*less than 1 month_ONC*`(for Gynae-Oncology) and each of them represent follow-up appointments that patients wait less than 1 month for each pathway.

  Hence, model activities can be gathered in 4 groups: First treatment activities, Follow-up treatment activities (less than 1 month, between 1 and 3, between 3 and 6, between 6 and 9, between 9 and 12, more than 12), Inpatient treatment activities (Inpatient, Inpatient_daycase), D&T activities (DAT).

- Resources

  In a simulation, resources are objects that are required at activities so that the activity can work on a work item (Simul8). In this study, most of resources represent clinics and there are 9 resources. For the Routine and Urgent parent-gynaecology pathways, resources are distributed according to clinic types (new outpatient resources and follow-up appointment resources). However, for Urodynamic and Gynae-Oncology pathways, resources are distributed according to the workload of clinics (busiest two clinics and other clinics). Although there is no this kind of distributed clinics in the real system, this process helps to comprehend the system. Furthermore, resources are

characterised as “Shift depended” and previously analysed clinic schedule (table 3) is entered as resource schedule.

In addition, another resource is assigned to inpatient treatments for Urgent, Routine and urodynamic clinics. Therefore, this resource does not represent clinics or doctors, it represents available beds. According to information which is attained from department and department website, the capacity of this resource is determined as 15 beds.

On the other hand, pooled resource which is a combination of resources is utilised for some scenarios such as adding an extra clinic to the system.

- End points

  An end point is where work items leave the system. In this model, there are two kind end points which are “discharged” and “other” for each pathway, thus model includes in total six end points.

- Work items

  These can be described as objects which move through the system. Therefore, work items of this simulation are patients.

- Route arrows

  They are used to connect simulation objects and help to understand the system. In this simulation, referral to first treatment pathways are drawn as blue, thick arrows. In addition, the main routes between new outpatient treatments, inpatient treatments, follow-up treatments and exits (discharged-other) are drawn with black arrows for each pathways. Moreover, all travel times were set to zero because patients do not spend time for travelling between stages in the elective model.

- Clock

  In a simulation, clock contains the time features of the model. In the model, the simulation clock was set to run from 08:00 until 17:00 Monday to Friday and the result collection period which defines the duration that simulation run is determined as 3 years. In addition to this, a warm-up period which is the time that the simulation will run before starting to collect results is set as 18 months (187,200 minutes) in order to reach a steady state in the system.

- Labels

  Attributes of entities are called labels in Simul8 software. Therefore, labels are used to identify the characteristics of patients which affect their pathway

direction and to facility programming of the model in this study. A list of labels which are used in the simulation can be seen in Figure 17.

Labels can be clarified as such; labels which are used for Gynae-Oncology patients are identified by adding "_onc" to end of the label name and similarly, Urodynamic patients' labels are identified by adding "_uro", Urgent pathway patients' labels are shown by adding "_U". Finally, the labels which do not have any adding (or adding "_R") is used for Routine Parent-gynaecology patients.

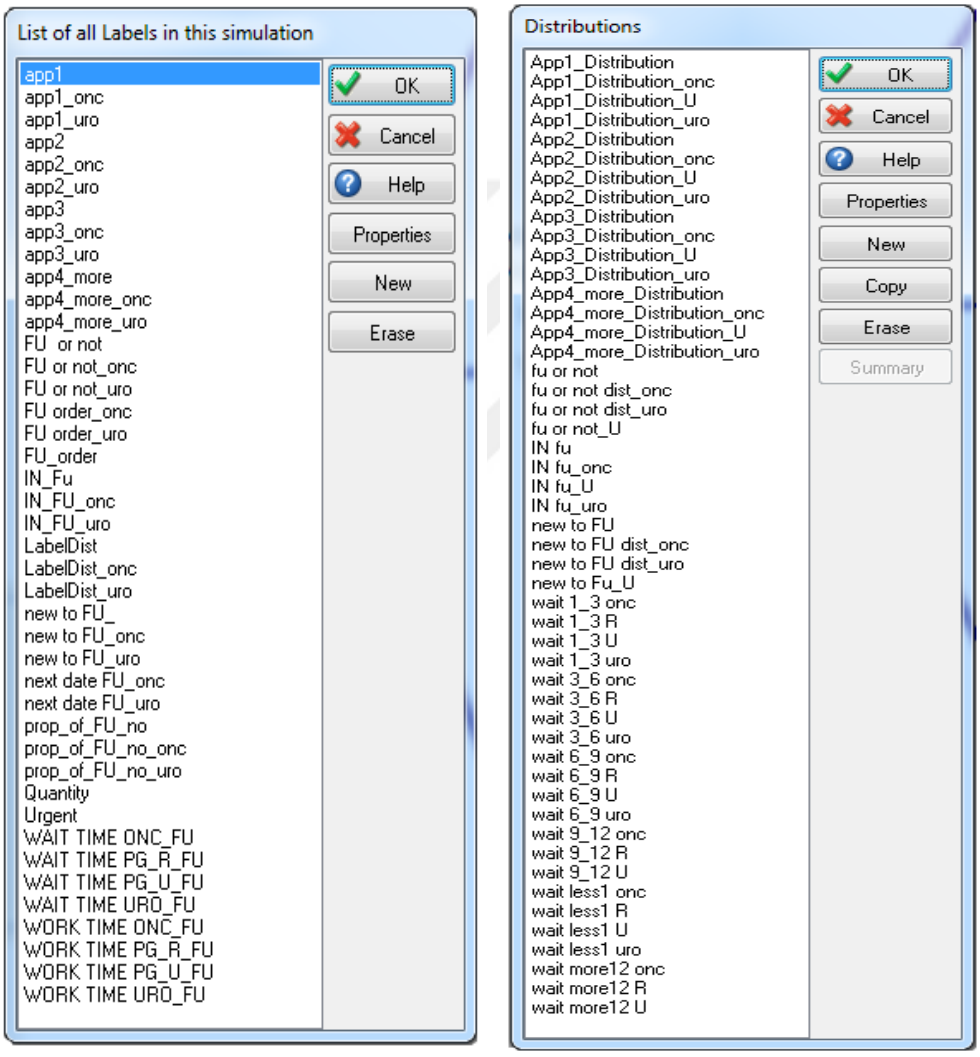


Figure 17 Labels and distributions of simulation model

- Distributions

Distributions are one of the most important tools to direct entities through in simulation. As well as providing some defined distributions, Simul8 enables to create different type distributions in a model. In this study, "probability profile", "label based" and "named" distributions are created and utilised to define the

distributions which are analysed in the first section of methodology. Again, a list of distributions which are used in the simulation can be seen in Figure 17. Similar to labels, distributions are identified by adding 'onc','uro','PG_R' and 'PG_U' end of the distribution name.

4.2.3. Overall model construction

The overall model consists of the three main patient pathways which are Urodynamic, Gynae-Oncology and Parent-gynaecology pathways. However, the Parent-gynaecology Pathway comprises of two sub-pathways which are the Urgent Parent-gynaecology and the Routine Parent-gynaecology pathways. Therefore, it can be stated that there are four different pathways in the simulation model. These pathways can be seen in Figure 19 which presents the overall simulation model. Fundamentally, Urodynamic, Gynae-Oncology, Urgent-Parent-gynaecology and Routine-Parent-gynaecology pathways have identical steps and processes. The difference is that patient distributions, which are analysed in the first part of methodology section, in each stage of pathways are dissimilar. Therefore, a pattern of pathways which represents the stages and features of pathways will be explained instead of explaining each pathway. However, some small differences between pathways will be also clarified. Figure 18 illustrates a pattern of pathways thus small parts of the model can be seen clearly.

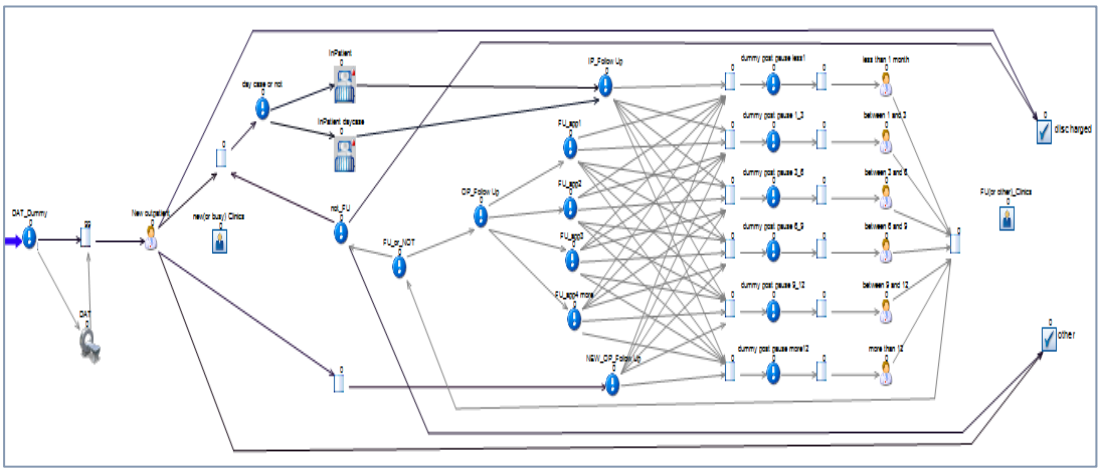


Figure 18 The pattern of pathways

Overall model can be clarified step by step as follows;

- Patients enter the system from the start point which represents referrals.
- Following the start point, there is a dummy activity which is called "*Accepted or Not*". Because some patients are not accepted to the department due to some

reasons. Therefore, this dummy activity distributes patients who are accepted and not accepted. Accepted patients continue their pathways while others out of the system.

- At the second step which is the "*Outpatient*" dummy activity, patients are distributed to their pathways according to the outpatient distribution by pathways (see Figure 1).
- After the patients are distributed within their pathways, it is seen that there is a small difference between the Parent-gynaecology and the other pathways. Patients who follow the Parent-gynaecology pathway are distributed as a Routine or an Urgent pathway according to the outpatient distribution of Parent-gynaecology (see Figure 1).
- After this stage, a pattern which is explained above can be followed. At the beginning of pathways, there is a dummy activity which is used to divide patients who visit D&T.
    - Patients who visit D&T services at least once in their treatments (new outpatient treatments, follow-up treatments or inpatient treatment) are calculated in "*DAT*" dummy activity according to results of D&T visiting analysis (see Table 4). It is important that the aim of this activity is to find out all patients who visit D&T not for just new patients.
- Before "*new outpatient"* activity, there is a queue which represents the outpatient waiting list. In this queue, the start-up values are defined as backlogs of the outpatient waiting list. These start-up values are found by calculating the difference of the total of patient numbers between 'outpatient activity' and 'outpatient waiting list' datasets (found 3094) at the first step and proportionally distributing these numbers to each pathway at the second step. Therefore, outpatient waiting list backlogs are 959 (0.94*0.33*3094) patients for Routine Parent-gynaecology, 1773 (0.94*0.66*3094) patients for Urgent Parent-gynaecology, 70 (0.022*3094) patients for Urodynamic and 99 (0.032*3094) patients for Gynae-Oncology pathways.
- The first real activity on each pathway is the "*new outpatient"* activity which new patients are treated. As a result of discussion with the service manager, the activity time is determined on an average of 20 minutes. Therefore, the triangular distribution (Lower=19, Upper=21, Mode=20) is used in this stage.

As a result of the first treatment outcomes (see Figure 3), patients are directed different paths which are discharged, other, inpatient and follow-up.

  - However, in Urgent Parent-gynaecology, there are two different directions after the new outpatient activity. Patients who are not suspected with cancer continue on the Urgent pathway while patients who are Urgent Cancer Suspected (USC) are directed to Gynae-Oncology pathway (see Figure 2). The USC patients again do not wait at Gynae-Oncology new outpatient queue. But, they wait for another queue at Gynae-Oncology pathway. Consequently, Gynae-Oncology pathway has two different queues for first treatment.

- A dummy activity which is called "*New OP follow-up*" is seen on the follow-up pathway. In this dummy activity, patients who are directed to follow-up appointment after the first outpatient activity are distributed to the follow-up appointment time periods according to the "new outpatient first follow-up time periods distribution"(see Table 1).
- Due to the fact that patients need to wait for their follow-up appointment, each follow-up appointment activity has a different queue. Because the minimum waiting time of each time period are different. These minimum waiting time which defines "predetermined waiting time" is called "pause". For example, some patients should wait a minimum of 3 months while some of them wait a minimum of 9 months according to the clinical outcomes. The amount of pause shows demand for activity. Therefore, the minimum, maximum and average waiting times (pauses) of follow-up time periods for each pathway are calculated. These calculated values are fitted to triangular distributions and these created distributions are entered to model as minimum waiting times. Waiting time periods (pauses) which are entered in the system as minutes can be seen in Table 6. These values are calculated based on simulation time (working times-8 hours in a day-5 days in a week).
  - Another component of the total waiting time is the delay which defines the 'waiting over clinically agreed target date'.(Wales Audit Office, 2015) Finding out of the amount of delays is crucial to see and solve bottlenecks in the system since delays mostly stem from operational reasons. For this aim, an extra dummy activity which is called "*dummy*

post pause" and an extra queue which presents "*delays*" are added to each follow-up treatment activates.

Follow Up time periods	Min waiting times	Max waiting times	Routine Average	Urgent Average	Oncology Average	Urodynamic Average
less than 1	0	10392	*4776*	*2376*	*5448*	*4488*
between 1-3	10392	31176	*19272*	*18816*	*17136*	*18408*
between 3-6	31176	62352	*41352*	*41592*	*37152*	*41880*
between 6-9	62352	93528	*68904*	*67896*	*66480*	*72000*
between 9-12	93528	124704	*105072*	*103824*	*103296*	
more than 12	124704	155880	*131448*	*131736*	*127680*	

Table 6 Average (minutes) of waiting time periods

- On the pathway, there are six activities which represent follow-up treatments. In the real system, there is no kind of follow-up activities, but this modelling technique provides more information to understand the system and to solve the system problems. Similar to new outpatient activity, the activity time is determined as a total average of 15 minutes in the light of information which attained from the service manager. Therefore, triangular distribution(Lower=14, Upper=16, Mode=15) is used in these activities.
- After follow-up treatment activities, patients are directed to new follow-up appointment or other process at the "*FU or not*" dummy variable according to the follow-up appointment outcomes (see Figure 8-9).
- Patients who are required follow-up treatment are directed to one of the "*FU app1", "FU app2", "FU app3*" or "*FU app4* more" dummy activities from the "*OP follow-up*" dummy activity according to follow-up the number of patients. For example, if a patient will attend another follow-up appointment after her second follow-up appointment, she is directed to "*FU app3*" dummy activity.
- For the next follow-up appointments, the follow-up patients are distributed from "*FU app(1,2,3,4more)*" dummy activities to follow-up time periods according to the distribution of the follow-up time periods against the follow-up numbers (see Figure 10, Figure 11, Figure 12, Figure 13)
- Patients who do not need another follow-up appointment are directed to the "*not FU*" dummy activity. According to follow-up appointment outcomes (see Figure 8-9), they are directed to discharged, other or inpatient pathways.
- Patients who are directed to inpatient pathway wait on the inpatient waiting list. Following this, they are directed from the "*day case or not*" dummy

activity to the "*inpatient*" or the "*inpatient day case*" activity. The activity time of "inpatient" is determined according to the results of the length of stay data (see Table 3, Figure 16) and the activity time of "*inpatient day case*" is determined (assumed) as the triangular distribution (Lower=60, Upper=240, Mode=150). Both of the inpatient activities are directed to follow-up appointments and the same follow-up appointment process which is explained above is repeated.

4.2.4. Model Assumptions

As it is mentioned in previous sections, the most important assumption is made for clinics. Although there is no separated clinic for follow-up or new outpatients in real, it is assumed that some clinics look for just new outpatients and others look for follow-up patients in Parent-gynaecology. Moreover, clinics of Urodynamic and Gynae-Oncology are separated according to the workload of clinics (busiest two clinics and other clinics). Additionally, different resource priorities are identified for some clinics to balance the workload of clinics.

In addition, patients whose follow-up number are defined as 0 (the number of their previous follow-up appointments are not known) are excluded due to lack of information. Furthermore, patients whose follow-up time period are defined as 0 (the time of their previous appointment is not known) are proportionally distributed to other time period groups.

Another assumption is considered in admin outcome groups. It is seen that patients who are discharged or referred to another healthcare professionals sometimes turn back to system and continue their pathways. Therefore, these patients are not counted in 'discharged' or 'other' groups.

4.2.5. What if scenarios

In this study, the main four scenarios are tested to decrease the waiting times of patients and to identify potential improvements to the Gynaecology Department.

The main idea of the first scenario is to add an extra clinic to the system. However, this scenario consists of two different versions. In the both versions, one extra clinic which runs 4 hours in a day and runs every day in a week is added. At the first version of the scenario, this clinic serves only new outpatients of Parent-gynaecology pathways (both Urgent and Routine). This scenario can be briefly stated that "what if

we run an extra one clinic which runs 4 hours in a day and serves only new outpatients in Parent-gynaecology". At the second version of the scenario, this clinic serves for the new and follow-up Parent-gynaecology patients in both Urgent and Routine pathways. Again, it is briefly specified that "what if we run an extra one clinic which run 4 hours in a day and serves both new and follow-up patients in Parent-gynaecology". For this aim, pooled resources for the new and follow-up clinics of Urgent and Routine pathways are created and the clinic is assigned by using these new pooled resources.

At the second scenario, treatment durations for each patient are changed and it tested that "what if treatment durations could be shortened". Similar to scenario 1, this scenario is applied in two manners. At the first situation which aims to show the total effect of decreasing treatment duration, new outpatient appointment time slots which is an average of 20(triangular distribution-Lower=19, Upper=21, Mode=20) minutes are decreased to 15(Lower=10, Upper=20, Mode=15) minutes and follow-up appointment time slots which average is 15(Lower=14, Upper=16, Mode=15) minutes declined to 10(Lower=5, Upper=15, Mode=10) minutes in each pathway. At the second situation which aims to understand the effect of decreasing the Routine follow-up treatment duration, Routine pathway follow-up appointment time slots which average is 15(Lower=14, Upper=16, Mode=15) minutes decreased to 12(Lower=10, Upper=16 Mode=12) minutes. Because of a specific treatment method (sterilization) which may be applied in the Routine pathway, this scenario is tested as an easy-applicable scenario.

At the third scenario, virtual review clinics which have less clinical time slots than other clinics are added for each follow-up appointments. In fact, there is no clinic which is physically added to the system in this scenario although activities which represent virtual reviews are added in the model. Therefore, this scenario can be defined as shifting some clinics as virtual review clinics. The maximum time slots of these clinics are determined as 9 minutes and it is assumed that 1 of 6 patients is treated by these clinics. For these activities, any extra resources is not identified and currently available resources are shared both virtual review and normal clinics for each follow-up time period activity.

Finally, one nurse led clinic which is run by registered nurses is added on the system as the fourth scenario. This nurse led clinic serves for all pathways. The time slots of this clinic are decided as an average of 20 minutes similar to the follow-up appointment clinics. It is assumed that 1 of 6 patients who attend follow-up appointments are directed to this clinic. One activity is added for each time period appointment activities similar to scenario 3. However, a new resource which is called the "*nurse led clinic*" is assigned for these activities differently from scenario 3. Two different versions are used in this scenario like the first and second scenario. The aim of the first version is to understand the total effect of the nurse-led clinic. Therefore, the clinic runs 4 hours per day; 5 days a week at the first version. However, the nurse led clinic run 4 hours per day; 1 day a week in the second version in order to understand the minimum effect of this clinic.

Scenarios which are tested need some modifications such as adding pooled resources or extra activities to the model. The modified models can be seen in appendix 3.

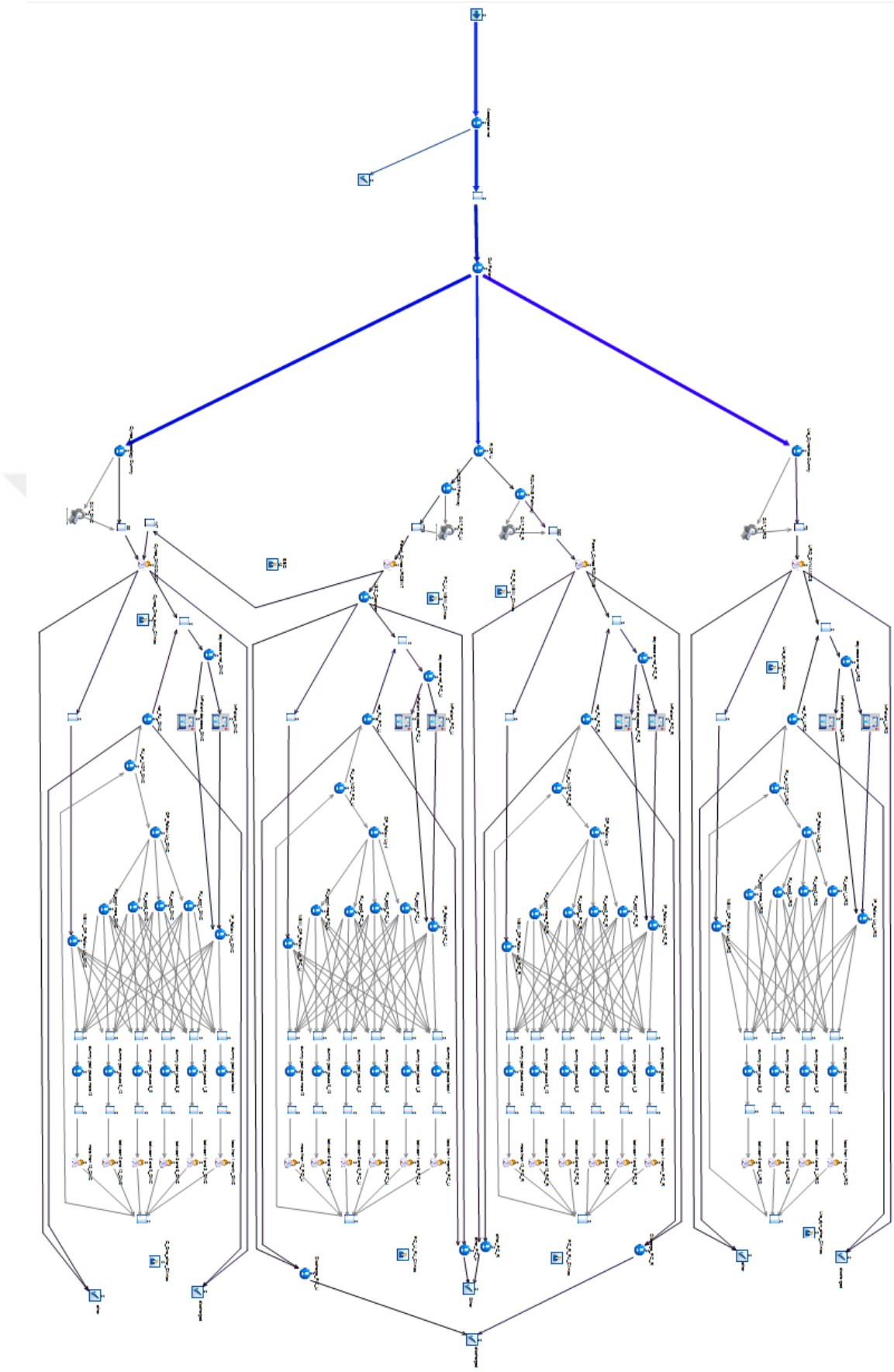


Figure 19 The overall Model

5. RESULTS

5.1. Model Verification and validation

Verification and Validation of the model are crucial to make sure that the designed model is appropriately built and developed for the task and reliable results are achieved from the model. Because of the importance of this, verification and validation of model are considered during each stage of the model building process and the final test is made at the end of the all process.

Verification of the model defines that theoretical model is correctly implemented. In other words, verification ensures that problem was solved correctly as it is defined in the literature. Therefore, data and each component which contribute the model were tested, analysed and results were discussed with experts, who works in Cardiff-Vale University Health Board, in order to ensure that model was solved correctly. In addition, previous studies which focus on problems that are similar with gynaecology pathway were examined. Also, as it is mentioned in methodology, data mining and grouping techniques were used to access core of the data. Furthermore, the simulation model was developed step by step by using information which was obtained from the regular meetings with project supervisors. At the first step of the model developing process, core patient pathways were built according to data analysis and the model was modified and widened according to meeting outcomes. For example, as a result of discussion with service manager, the Parent-gynaecology pathway was divided to two pathways as Routine and Urgent to solve department problem, correctly. The outcomes of core model which has new, follow-up and inpatient treatment stages were tested to ensure that model was built correctly. Following this, follow-up appointment stages was developed by finding follow-up appointment numbers. In addition, follow-up appointment time periods were integrated with follow-up appointment numbers and accuracy of this sub-system was tested apart from main model. Finally, all built and tested sub-models were gathered and the final model were built, improved and its verification was tested. The main verification process is illustrated in a diagram which is seen Figure 20.

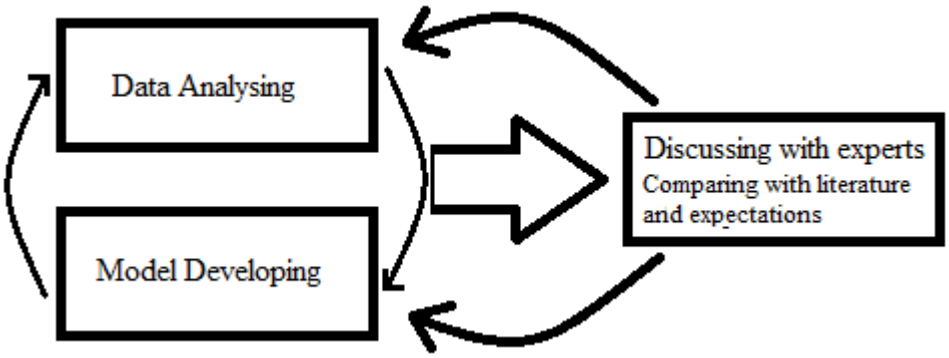


Figure 20 The Model verification diagram

In this process, ten model which each of them has (average) 5 version were made by adding to each other until final model was achieved. The screenshots of these models can be found in appendix 3. On the other hand, waiting time tables which is seen at the next section includes in pause times which are input of the model. The aim of representing pause times is to support verification of model.

Validation defines the accuracy of the model with regards to representing of the real system. In other words, validated model expresses that the correct problem was solved as it is described in the literature. Validation of model was discussed with the service manager, the health board team and supervisors. The outcomes of each step of the model developing process were compared with real data and experiences of stakeholders. In addition to this, the number of trials which can present accurate results whilst consuming minimum time is chosen to be 100. Also it is seen that 100 trials were found to be enough in some previous studies. Therefore, 100 replications (trials) of the final model were used to generate results with 95% confidence intervals. These base scenario results are compared with real data and expert opinion. For example, the key indicator was the total number of patients in the simulation versus real data. It was found that 53376 (with "not accepted" patients) patient enter the simulation in 3 years (after 1.5 year warm up period), compared to 56203 in the 'referral' dataset. Furthermore, as it is seen in Figure 21, it is found that total 30880 patients receive a follow-up appointment at least once in the simulation, which is comparable to the as 25588 observed in the real data.

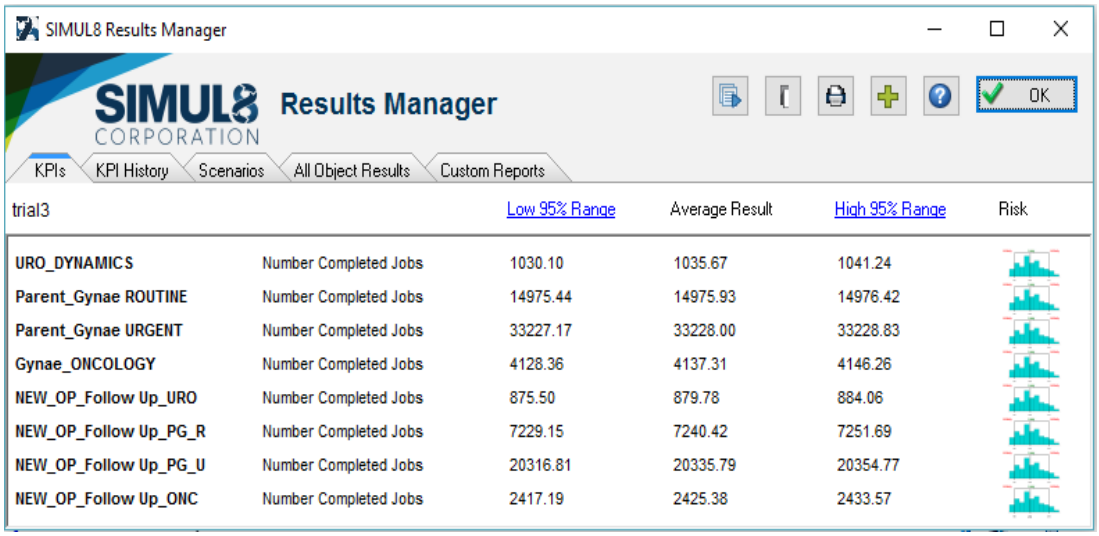


Figure 21 Trial results for validation

The outputs of the simulation model are adequately consistent with the real data and meet the expectations of the stakeholders. The next section will present the results of the simulation study.

5.2. Simulation Model Results

The results which are obtained after running the simulation 100 times are presented in two parts. Firstly, the demand on the system was calculated using the number of patients in each pathway. Secondly, waiting times of new and follow-up appointments are revealed as a performance measure by comparing each other.

Stage \ pathway	**Routine-Parent**	**Urgent- Parent**	**Oncology**	**Urodynamic**	**Total**
New Outpatient	14976	33232	4030	1012	53250
Less than 1 month	7452	45563	7161	1512	61688
Between 1 and 3	8895	18140	4737	2486	34258
Between 3 and 6	8489	10636	2526	1150	22801
Between 6 and 9	2552	8009	738	194	11493
Between 9 and 12	589	711	56	0	1356
More than 12	68	691	60	0	819
Inpatient	2580	3737	3256	13	9586
Inpatient day case	1426	2400	735	669	5230
D&T	2943	6692	984	1038	11657
Other	6346	6522	2261	727	15856
Discharged	8238	22800	1677	243	32958

Table 7 Demand for services

52221 of 53959 referred patients are accepted into the system during the simulation run time (3 years). Table 7 documents where these 'accepted' patients incur demand on the system. The total number of new outpatient appointments is more than the number 'accepted' because Urgent Suspected Cancer (USC) patients incur demand in both Urgent and Oncology pathways.

One of the most important results is seen at demand for follow-up appointment time periods. It is seen that most patients who are required follow-up appointment are accepted less than 1 month for their follow-up appointments in Urgent, gynae-oncology pathways and in total. The busiest follow-up time period for Routine and urodynamic pathways is between 1 and 3 months-follow-up time period. However, a patient might attend follow-up appointments three times and each of them might be in different (or same) time periods, so this patient is counted three times in different (or same) time periods. The total number of patients who visit D&T at least once in their pathways is 11657 and most of them are from Urgent parent-gynaecology pathway. Furthermore, as it is observed in Table 7, total 15856 patients disappear in the system because of the reasons such as "did not attend (more than once)" or "transferred to another H\C professional". It is remarkable that although the biggest "other (dissappering)" number is seen in Urgent pathway, the smallest "other group" ratio, which is calculated by diving other to new outpatient number, is seen in this pathway. Finally, two thirds of 'accepted' patients (32958) are discharged within 3 years. So, follow-up has a significant drain on resources.

The results of waiting times which includes in pause, delay are presented in following tables. In addition, tables illustrate the overdue rates which express the delay represented as percentage of the pause which is the predetermined waiting time.

Parent – Routine	Pause(Week)			Delay (Week)			Overdue (%)
	Min	Mean	Max	Min	Mean	Max	%
New	-	-	-	18,04	27,19	36,15	-
Less than 1 month	0,04	2,11	4,30	0,00	0,08	0,46	4,02
Between 1 and 3 months	4,37	8,42	12,94	0,00	0,35	1,58	4,14
Between 3 and 6 months	13,03	18,70	25,92	0,00	0,17	0,87	0,90
Between 6 and 9 months	26,03	31,13	3,87	0,00	0,02	0,14	0,07
Between 9 and 12 months	39,34	44,86	51,51	0,00	0,02	0,06	0,04
More than 12 months	53,02	57,39	63,30	0,00	0,02	0,04	0,03

Table 8 Waiting times of Routine-Parent-gynaecology pathway

Table 8 demonstrates waiting times of Routine Parent-gynaecology pathway where new outpatients wait on average 27 weeks for their first outpatient appointments, and a maximum of 36 weeks. The busiest follow-up time period is between 1 and 3 months, with patients on average 3 days delayed. There are no significant delays for other follow-up time periods in Routine pathway

Parent - Urgent	Pause			Delayed			Overdue (%)
	Min	Mean	Max	Min	Mean	Max	%
New	-	-	-	6.63	7.33	8.02	-
Less than 1 month	0.01	1.78	4.31	0.00	1.82	4.30	102.41
Between 1 and 3 months	4.38	8.40	12.96	0.00	0.02	0.12	0.19
Between 3 and 6 months	13.07	18.78	25.86	0.00	0.01	0.08	0.06
Between 6 and 9 months	26.02	31.04	38.79	0.00	0.01	0.08	0.04
Between 9 and 12 months	39.34	44.78	51.25	0.00	0.01	0.04	0.02
More than 12 months	0.52	5.73	64.07	0.00	0.01	0.04	0.17

Table 9 Waiting times of Urgent-Parent-gynaecology pathway

Table 9 presents waiting times of Urgent Parent-gynaecology pathway, where new outpatients wait on average 7.5 weeks for their first outpatient appointment. Unlike the Routine pathway, the busiest follow-up time period is less than 1 month. Although the overdue rate of less than 1 month follow-up time period is quite high, total waiting times of patients do not go beyond 1 month. Because, the sum of average pause and delay for less than 1 month (Urgent) follow-up time period is less than 4 weeks.

Gynae-Oncology	Pause			Delayed			Overdue (%)
	Min	Mean	Max	Min	Mean	Max	%
New	-	-	-	0,00	1,59	5,84	-
Less than 1 month	0,05	2,19	4,30	0,00	0,14	0,43	6,20
Between 1 and 3 months	4,38	8,16	12,87	0,00	0,57	1,80	7,04
Between 3 and 6 months	1,31	18,12	25,79	0,00	0,24	0,62	1,32
Between 6 and 9 months	26,01	31,01	3,83	0,00	0,17	0,55	0,56
Between 9 and 12 months	39,51	44,26	51,02	0,00	0,12	0,52	0,26
More than 12 months	5,24	56,79	64,32	0,01	0,17	0,44	0,29

Table 10 Waiting times of Gynae-Oncology pathway

Table 10 illustrates waiting times of Gynae-Oncology pathway. The waiting time for new outpatient appointment is average 2 weeks in Gynae-Oncology pathway. Moreover, all delays of follow-up appointment time periods are less than 1 week. However, it is seen that the highest overdue rate is seen in between 1 and 3 months follow-up time period by 7,04%.

Urodynamics	Pause			Delayed			Overdue (%)
	Min	Mean	Max	Min	Mean	Max	%
New	-	-	-	0,00	8,87	19,59	-
Less than 1 month	0,08	2,05	4,30	0,00	0,35	1,24	**16,90**
Between 1 and 3 months	4,45	8,37	12,77	0,00	0,22	0,70	**2,67**
Between 3 and 6 months	13,04	18,83	25,58	0,00	0,28	0,94	**1,48**
Between 6 and 9 months	26,52	31,85	38,03	0,00	0,34	1,50	**1,07**

Table 11 Waiting times of Urodynamic pathway

Finally, the waiting times of Urodynamic pathway is presented in Table 11. For this pathway, new outpatient appointment's waiting time is found as average 8 weeks. Also, less than 1 month time period is seen as the busiest follow-up time period for this pathway according to overdue rate. Similar to Gynae-Oncology pathway, delays of follow-up appointment time periods are less than one week.

Consequently, the results can be illustrated in graphs in order to see differences and to compare each other. Therefore, Figure 22 which demonstrates new outpatient appointment waiting times of pathways and Figure 23 shows the delays of follow-up-appointment time periods are presented.

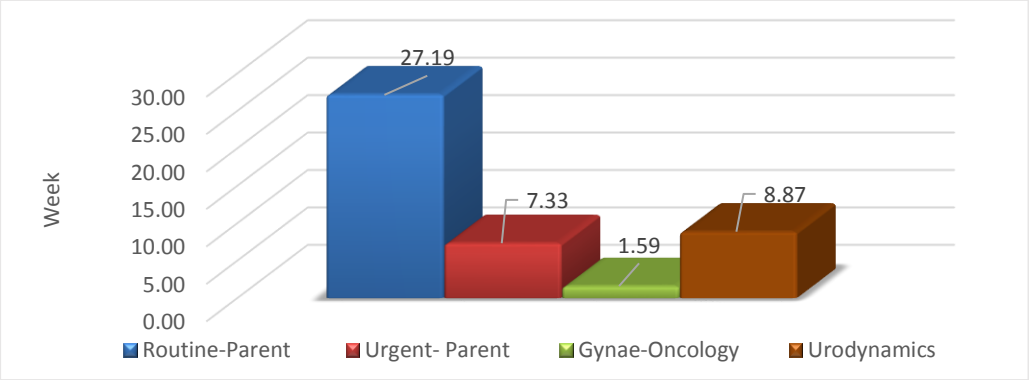


Figure 22 New outpatient appointment waiting times

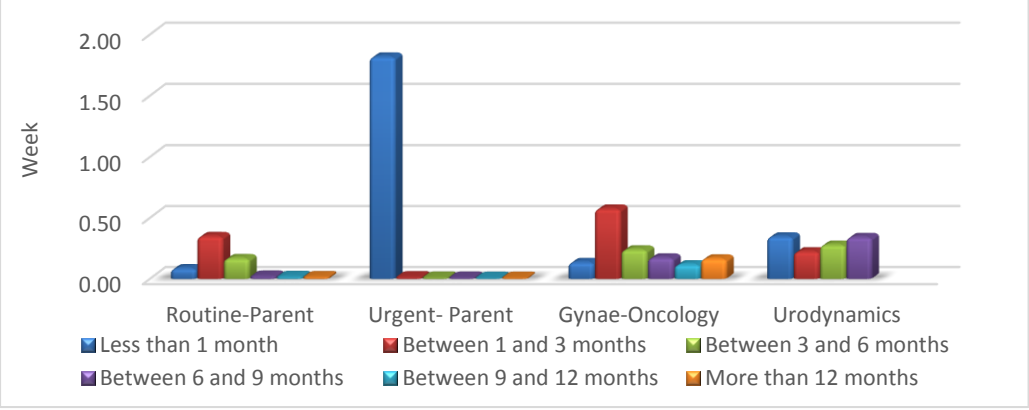


Figure 23 Delays of follow up-appointment time periods

It should be stated that resources were not prioritised in Urgent and Routine Parent-gynaecology pathways as a queening rules. However, resources were shared based on the volume of new and follow appointments in Gynae-Oncology and Urodynamic pathways due to the low demand for these pathways. Therefore, resources were prioritised between new and follow-up appointments for in Gynae-Oncology and Urodynamic pathways. As a result of the 'priority' process, the simulation results were found very consistent. As a feature of the simulation, it is found that the longest waiting time for new outpatient appointment is seen in Routine Parent-gynaecology pathway (see Figure 22) and the longest delay time for follow-up appointment is found in Urgent-Parent-gynaecology pathway (see Figure 23). Therefore, the scenarios should focus on solving these bottlenecks on the system.

5.3. 'What if' Scenarios Results

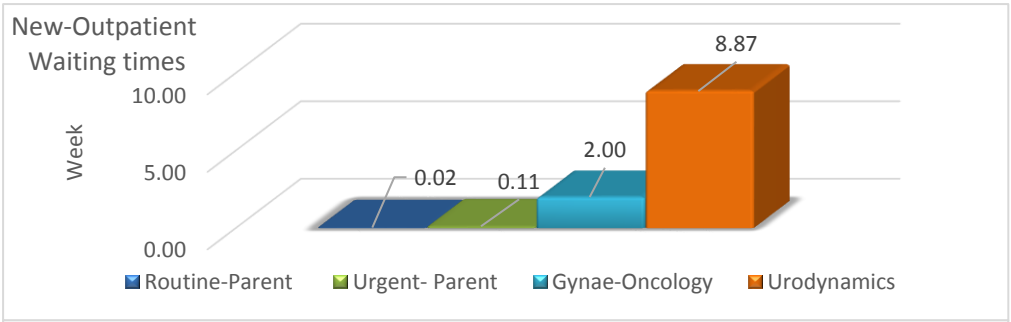
5.3.1. Scenario 1 Results

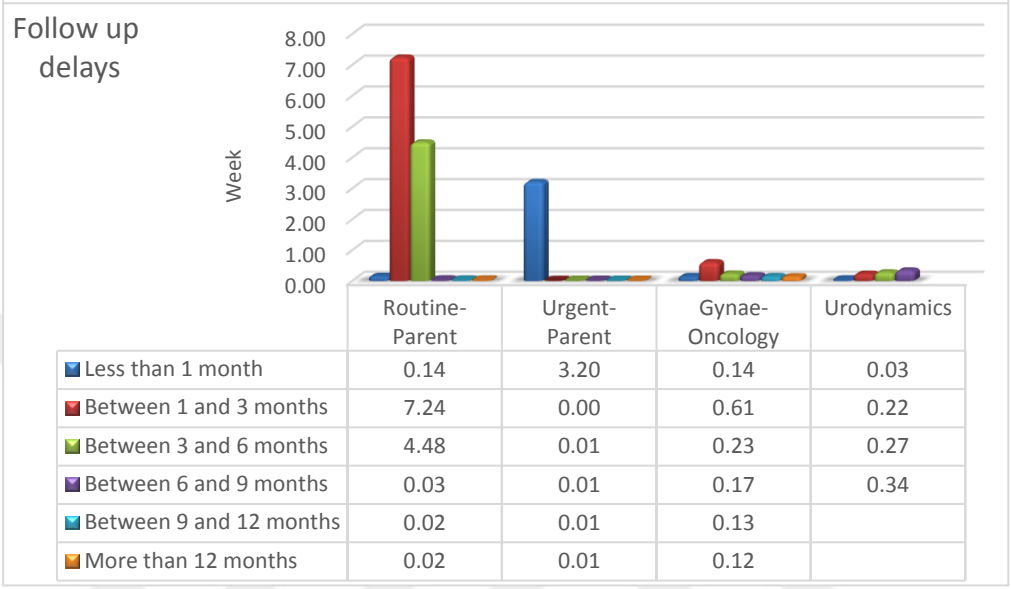
In this scenario, an extra clinic, which runs 4 hours in a day and runs every day in a week, was added to system. However, as it is mentioned in methodology section, this clinic was tested in two different situations:

- Scenario 1.1: the clinic serves only new outpatients of Urgent and Routine Parent-gynaecology
- Scenario 1.2: the clinic serves for new and follow-up (Urgent and Routine) Parent-gynaecology patients.

Scenario 1.1 significantly decreased new outpatient waiting times for Routine and Urgent pathways (see Figure 24). However, delays of some follow-up appointment time periods increased (especially for Routine pathway) causing congestion in the system.

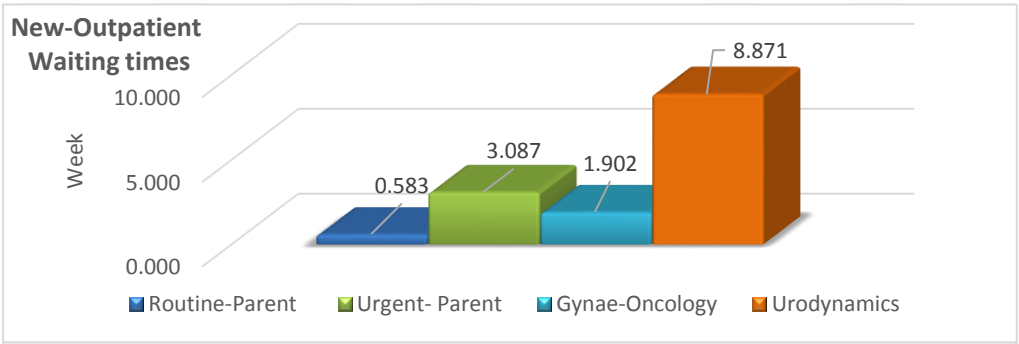
Figure 25 presents scenario 1.2. Similar to scenario 1.1, scenario 1.2 substantially reduced new outpatient waiting times for Routine and Urgent pathways. Furthermore, decreased delays for all follow-up appointment time periods in both Urgent and Routine pathway.

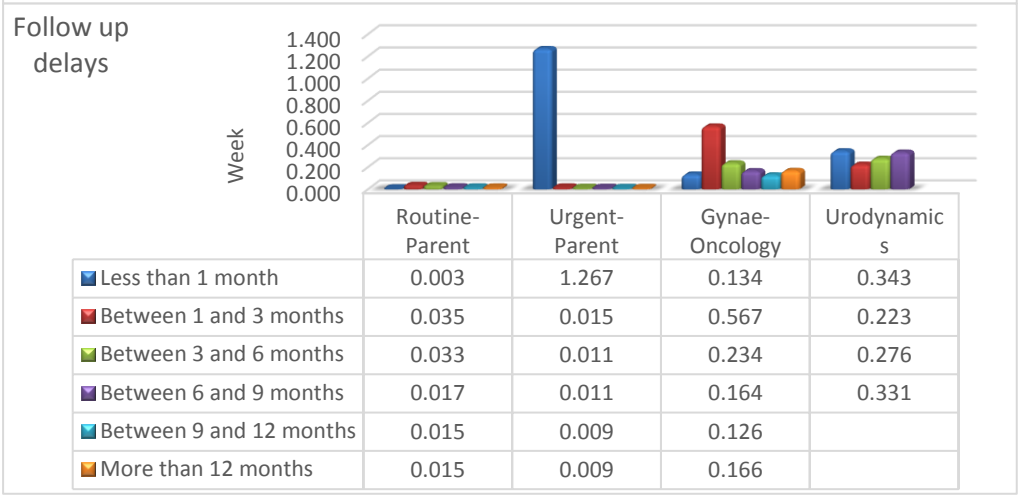




	Routine-Parent	Urgent-Parent	Gynae-Oncology	Urodynamics
Less than 1 month	0.14	3.20	0.14	0.03
Between 1 and 3 months	7.24	0.00	0.61	0.22
Between 3 and 6 months	4.48	0.01	0.23	0.27
Between 6 and 9 months	0.03	0.01	0.17	0.34
Between 9 and 12 months	0.02	0.01	0.13	
More than 12 months	0.02	0.01	0.12	

Figure 24 Results of scenario 1.1





	Routine-Parent	Urgent-Parent	Gynae-Oncology	Urodynamics
Less than 1 month	0.003	1.267	0.134	0.343
Between 1 and 3 months	0.035	0.015	0.567	0.223
Between 3 and 6 months	0.033	0.011	0.234	0.276
Between 6 and 9 months	0.017	0.011	0.164	0.331
Between 9 and 12 months	0.015	0.009	0.126	
More than 12 months	0.015	0.009	0.166	

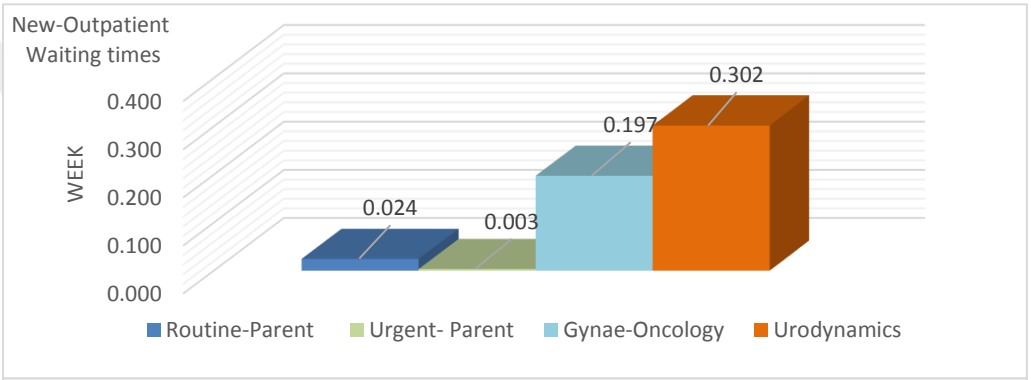
Figure 25 Results of scenario 1.2

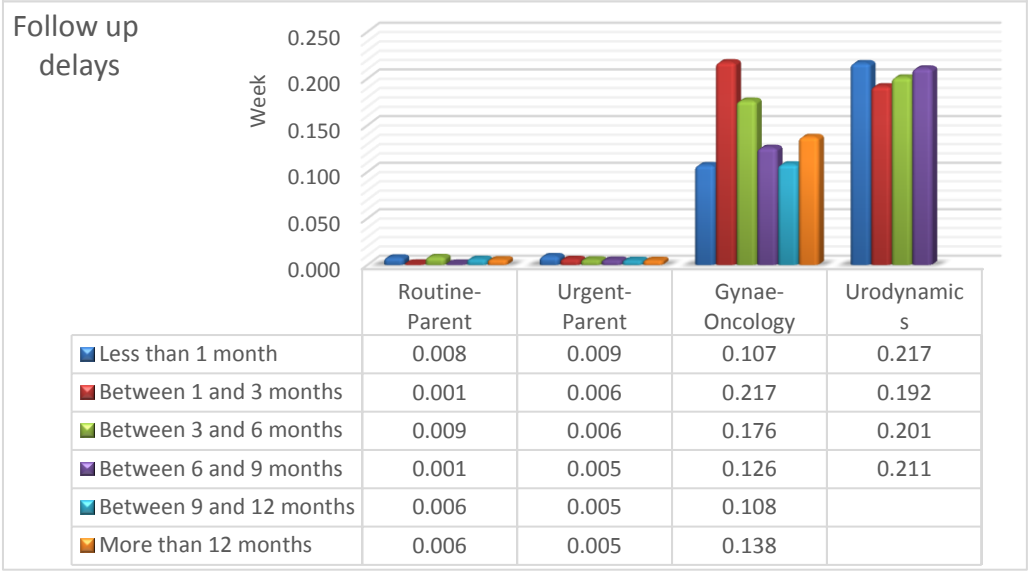
5.3.2. Scenario 2 Results

In scenario 2, treatment durations for each patient are decreased in two ways:

- New outpatient appointment time slots are decreased to 15 minutes and follow-up appointment time slots declined to 10 minutes.
- Routine pathway follow-up appointment time slots decreased to 12 minutes.

As it is seen in the Figure 26 which presents scenario 2.1 results, decreasing appointment time slots (treatment durations) for new outpatients and follow-up appointments considerably decreased waiting times and delays. In other words, this scenario eliminated all delays for Routine and Urgent parent-gynaecology pathways.

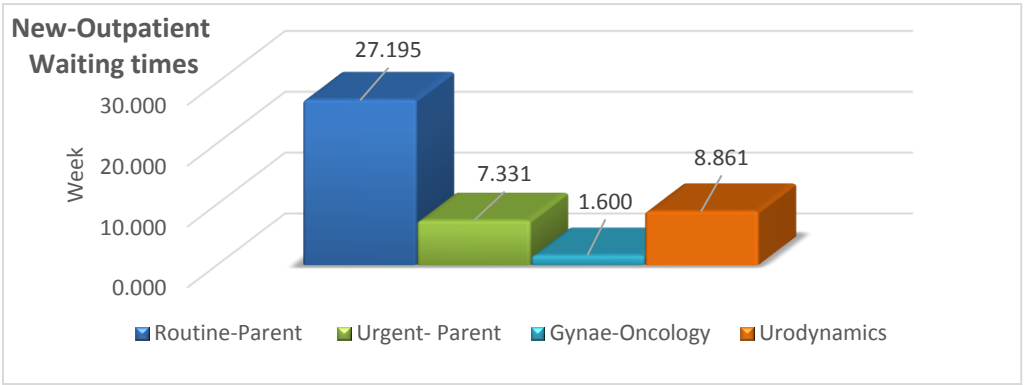


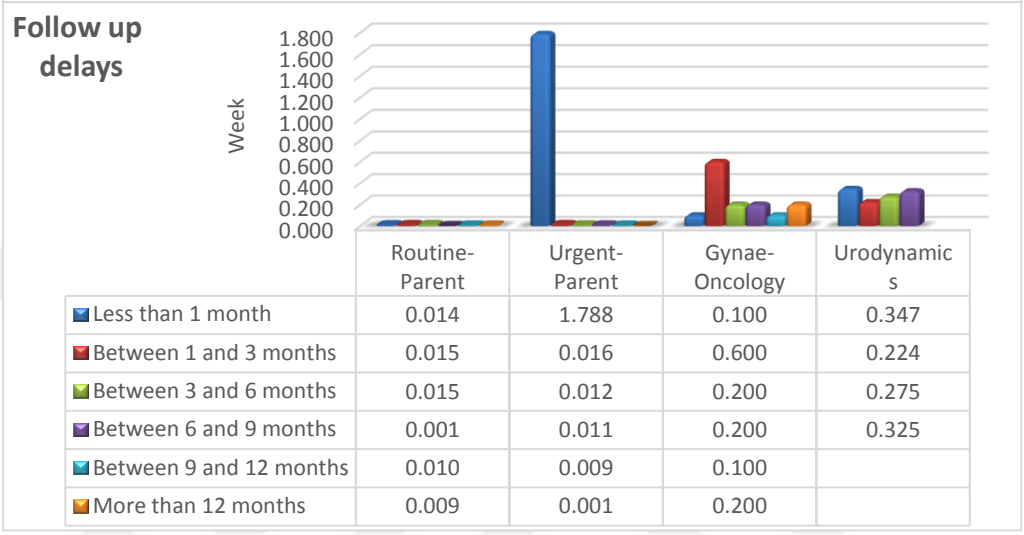


	Routine-Parent	Urgent-Parent	Gynae-Oncology	Urodynamics
Less than 1 month	0.008	0.009	0.107	0.217
Between 1 and 3 months	0.001	0.006	0.217	0.192
Between 3 and 6 months	0.009	0.006	0.176	0.201
Between 6 and 9 months	0.001	0.005	0.126	0.211
Between 9 and 12 months	0.006	0.005	0.108	
More than 12 months	0.006	0.005	0.138	

Figure 26 Results of scenario 2.1

Figure 27 shows scenario 2.2 results. According to this result, a slight decrease in Routine pathway follow-up appointment time slots made a difference with regards to delays of follow-up time periods.





	Routine-Parent	Urgent-Parent	Gynae-Oncology	Urodynamics
Less than 1 month	0.014	1.788	0.100	0.347
Between 1 and 3 months	0.015	0.016	0.600	0.224
Between 3 and 6 months	0.015	0.012	0.200	0.275
Between 6 and 9 months	0.001	0.011	0.200	0.325
Between 9 and 12 months	0.010	0.009	0.100	
More than 12 months	0.009	0.001	0.200	

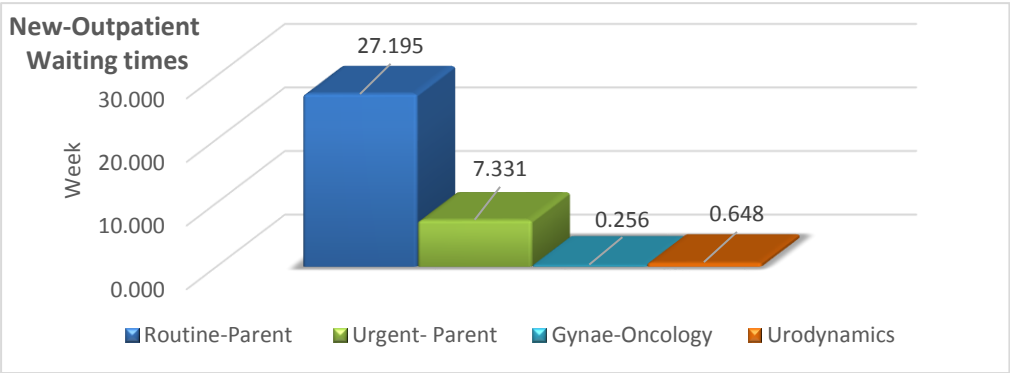
Figure 27 Results of scenario 2.2

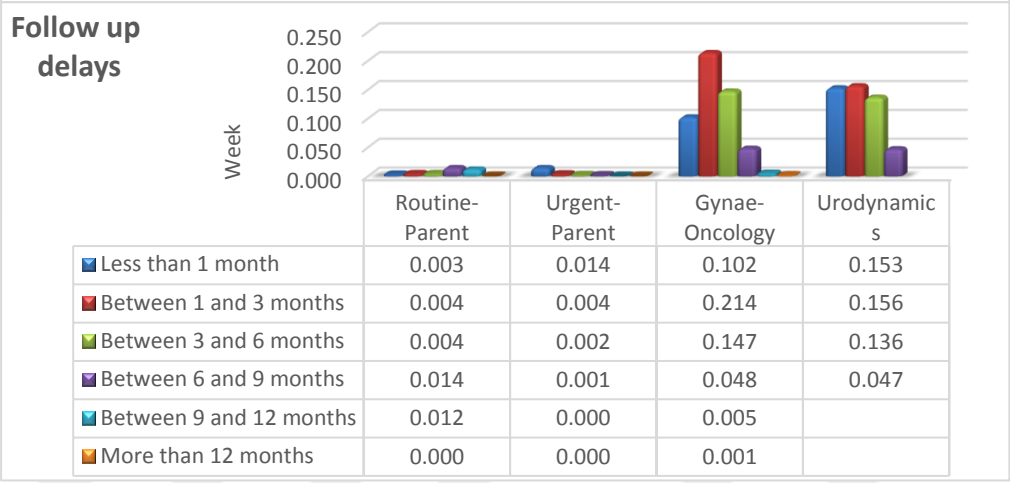
Consequently, scenario 2 helped to decrease follow-up delays. Scenario 2.1 solved all congestions and made the system very effective. However, it represents the perfect scenario. Therefore, scenario 2.2 is seen more feasible to implement although it does not affect all delays and waiting times.

5.3.3. Scenario 3 Results

In this scenario, some clinics were shifted as virtual review clinics for follow-up appointments. The maximum time slots of these clinics are determined as 9 minutes and it is assumed that 1 patient in 6 is treated by these clinics.

As a result of this scenario (Figure 28), delays are decreased significantly for each pathway as expected. Moreover, shifting some follow-up clinics to be virtual review clinics shortened new outpatient waiting times of Gynae-oncology and Urodynamics pathways as resources (clinics) are shared within the pathways based on the volume of appointments.





	Routine-Parent	Urgent-Parent	Gynae-Oncology	Urodynamics
Less than 1 month	0.003	0.014	0.102	0.153
Between 1 and 3 months	0.004	0.004	0.214	0.156
Between 3 and 6 months	0.004	0.002	0.147	0.136
Between 6 and 9 months	0.014	0.001	0.048	0.047
Between 9 and 12 months	0.012	0.000	0.005	
More than 12 months	0.000	0.000	0.001	

Figure 28 Results of scenario 3

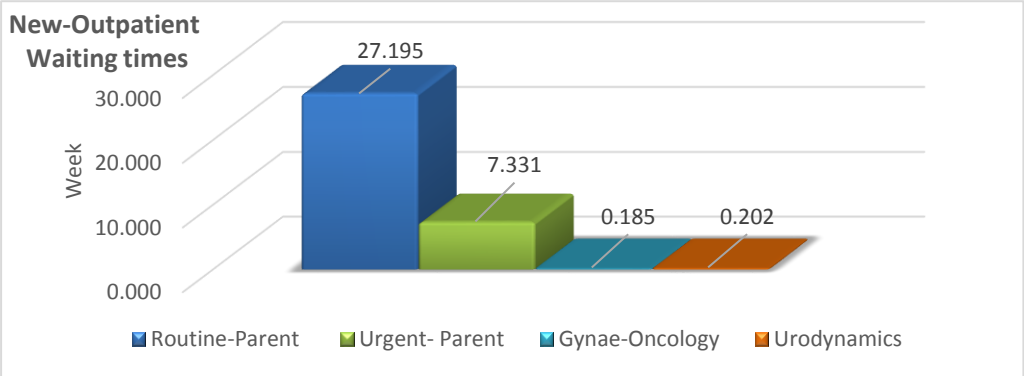
5.3.4. Scenario 4 Results

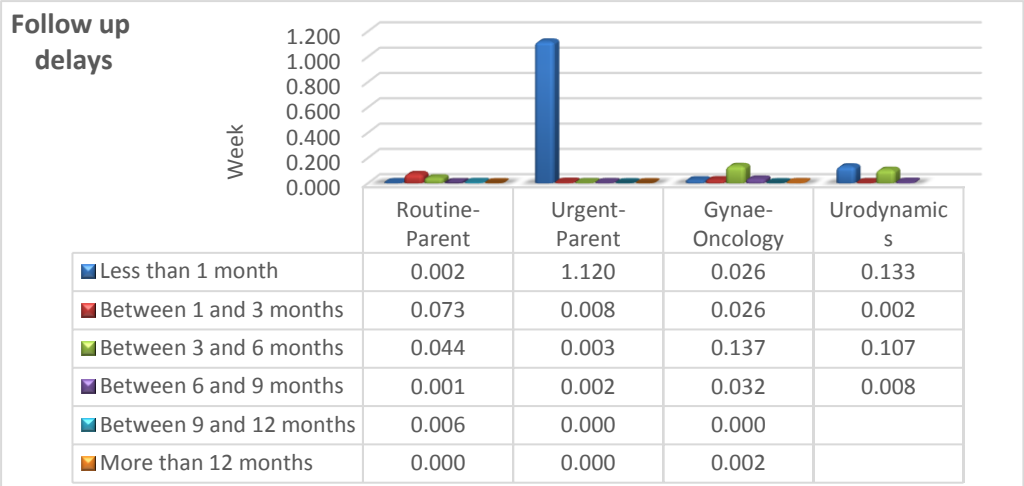
One nurse led clinic which serves all pathways is added in the fourth scenario. It is assumed that 1 in 6 patients are directed to this clinic and appointments are on average 20 minutes. The clinic runs 4 hours per day; however,

- In scenario 4.1, the clinic runs 5 days a week
- In scenario 4.2, the clinic runs 1 days a week

Figure 29 shows that adding one nurse led clinic which run 5 days (20 hours) in a week decreased all follow-up time period delays for each pathway. Moreover, nurse led clinic is shortened new outpatient waiting times of Gynae-oncology and Urodynamic pathways similar to scenario 3.

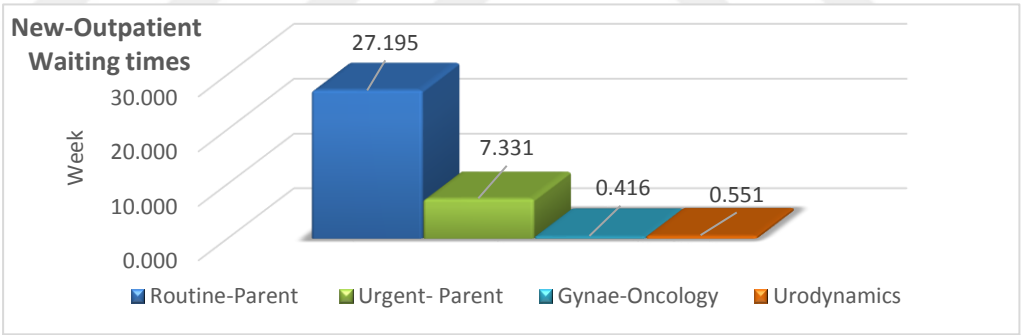
Figure 30 shows that adding one nurse led clinic which run 1 day (4 hours) in a week helped to decline delays of follow-up time periods although it did not eliminate all delays.

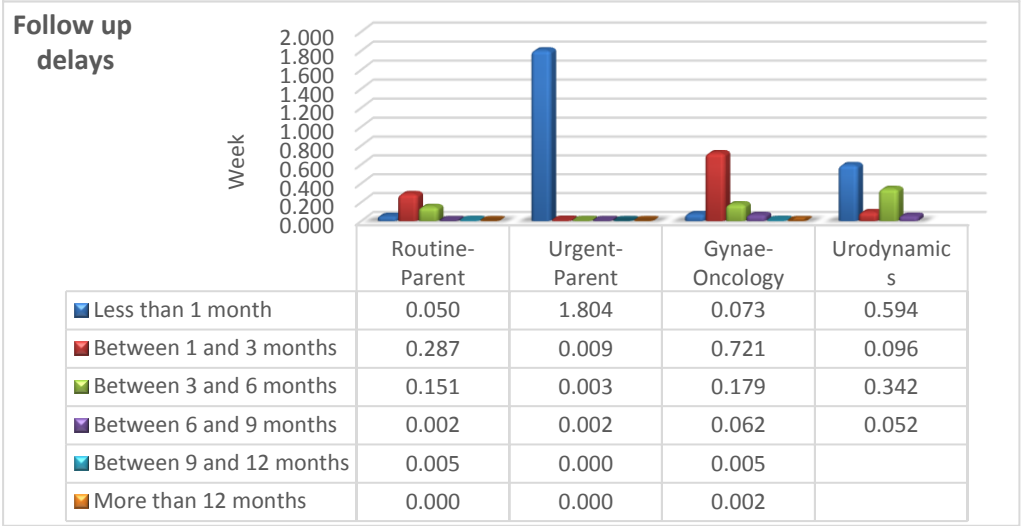




	Routine-Parent	Urgent-Parent	Gynae-Oncology	Urodynamics
Less than 1 month	0.002	1.120	0.026	0.133
Between 1 and 3 months	0.073	0.008	0.026	0.002
Between 3 and 6 months	0.044	0.003	0.137	0.107
Between 6 and 9 months	0.001	0.002	0.032	0.008
Between 9 and 12 months	0.006	0.000	0.000	
More than 12 months	0.000	0.000	0.002	

Figure 29 Results of scenario 4.1





	Routine-Parent	Urgent-Parent	Gynae-Oncology	Urodynamics
Less than 1 month	0.050	1.804	0.073	0.594
Between 1 and 3 months	0.287	0.009	0.721	0.096
Between 3 and 6 months	0.151	0.003	0.179	0.342
Between 6 and 9 months	0.002	0.002	0.062	0.052
Between 9 and 12 months	0.005	0.000	0.005	
More than 12 months	0.000	0.000	0.002	

Figure 30 Results of scenario 4.2

In addition, presenting all scenario results together can be helpful to see differences between scenarios and to understand their effects. Therefore, overall scenario results can be seen in Table 12 which is discussed in the next section of this study. In the Table 12, $\bar{x}$ represents mean(average) of delay (as week), SD represent standard deviation of new outpatient waiting times (as week),% represent overdue rates of follow-up time periods. However, the table will be interpreted and discussed in the next section of this study.

Overall Results		Base Scn		Scn 1.1		Scn 1.2		Scn 2.1		Scn 2.2		Scn 3		Scn 4.1		Scn 4.2	
Waiting time	Pathway	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
New	Routine	27,19	5,1	0,02	0,0	0,58	0,1	0,02	0,0	27,19	3,8	27,19	3,8	27,19	3,8	27,19	3,8
	Urgent	7,33	0,3	0,11	0,3	3,09	0,9	0,00	0,0	7,33	0,3	7,33	0,3	7,33	0,3	7,33	0,3
	Oncology	1,59	1,6	2,00	1,6	1,90	1,9	0,20	0,2	1,60	1,6	0,26	0,2	0,18	0,2	0,42	0,3
	Urodyn	8,87	6,0	8,87	6,0	8,87	6,0	0,30	0,2	8,86	6,0	0,65	0,5	0,20	0,2	0,55	0,5
FU-Delay	Pathway	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%	$\bar{x}$	%
Less than 1 month	Routine	0,08	4,0	0,14	6,6	0,00	1,3	0,01	4,8	0,02	0,8	0,00	0,2	0,00	0,1	0,06	2,7
	Urgent	1,82	102,4	3,20	180,4	1,27	71,4	0,01	0,5	1,79	100,8	0,01	0,8	1,12	63,1	1,80	101,6
	Oncology	0,14	6,2	0,14	6,2	0,13	61,3	0,11	4,5	0,10	4,5	0,10	4,7	0,03	1,2	0,07	3,3
	Urodyn	0,35	16,9	0,03	1,7	0,34	16,8	0,22	15,0	0,35	16,9	0,15	7,5	0,13	6,5	0,59	29,1
Between 1 and 3 months	Routine	0,35	13,7	7,24	85,8	0,04	0,4	0,01	14,3	0,00	0,0	0,00	0,0	0,07	0,1	0,29	15,3
	Urgent	0,02	0,2	0,00	0,0	0,02	1,8	0,01	0,1	0,02	0,2	0,00	0,0	0,01	0,1	0,01	0,1
	Oncology	0,57	7,0	0,61	7,4	0,57	7,0	0,22	7,3	0,60	7,3	0,21	2,6	0,03	0,3	0,72	8,8
	Urodyn	0,22	2,7	0,22	26,8	0,22	26,6	0,19	2,4	0,22	26,8	0,16	1,9	0,00	0,0	0,10	1,1
Between 3 and 6 months	Routine	0,17	0,2	4,48	23,5	0,03	0,2	0,01	0,0	0,02	0,1	0,00	0,0	0,04	5,0	0,15	1,6
	Urgent	0,01	0,1	0,01	0,1	0,01	0,1	0,01	0,0	0,01	0,1	0,00	0,0	0,00	0,0	0,00	0,0
	Oncology	0,24	1,3	0,23	1,3	0,23	1,3	0,18	1,1	0,20	1,1	0,15	0,8	0,14	0,8	0,18	1,0
	Urodyn	0,28	1,5	0,27	1,4	0,28	1,5	0,20	1,6	0,27	1,5	0,14	0,7	0,11	0,6	0,34	1,8
Between 6 and 9 months	Routine	0,02	0,1	0,03	0,1	0,02	0,1	0,01	0,0	0,00	0,0	0,00	0,0	0,00	0,0	0,00	0,0
	Urgent	0,01	0,0	0,01	0,0	0,01	0,0	0,01	0,0	0,01	0,0	0,00	0,0	0,00	0,0	0,00	0,0
	Oncology	0,17	0,6	0,17	5,4	0,16	0,5	0,13	0,6	0,20	0,6	0,05	0,2	0,03	0,1	0,06	0,2
	Urodyn	0,34	1,1	0,34	1,1	0,33	1,0	0,21	0,9	0,33	1,0	0,05	0,1	0,01	0,0	0,05	0,2
Between 9 and 12 months	Routine	0,02	0,1	0,02	0,0	0,02	0,0	0,01	0,0	0,01	0,0	0,00	0,0	0,00	0,0	0,00	0,0
	Urgent	0,01	0,0	0,01	0,0	0,01	0,0	0,00	0,0	0,01	0,0	0,00	0,0	0,00	0,0	0,00	0,0
	Oncology	0,12	0,3	0,13	0,3	0,13	0,3	0,11	0,2	0,10	0,2	0,01	0,3	0,00	0,0	0,01	0,0
	Urodyn																
More than 12 months	Routine	0,02	0,0	0,02	0,0	0,01	0,0	0,01	0,0	0,01	0,0	0,00	0,0	0,00	0,0	0,00	0,0
	Urgent	0,01	0,2	0,01	0,0	0,01	0,0	0,00	0,0	0,00	0,0	0,00	0,0	0,00	0,1	0,00	0,0
	Oncology	0,17	0,3	0,12	2,2	0,17	0,3	0,14	0,4	0,20	0,4	0,00	0,1	0,00	0,0	0,00	0,0
	Urodyn																

Table 12 Overall Results

6.DISCUSSION

The simulation model was found considerably consistent and acceptable according to the results which meets expectations. Moreover, the results enabled to see bottlenecks and the efficiency of the system. It has been found that the busiest pathway is the Parent-Gynaecology pathway by more than 15,000 patients each year and most of the Parent-Gynaecology patients follows the Urgent pathway. In addition, relatively less patients are seen in Gynae-oncology and Urodynamic pathways. Especially, the total number of patients in the urodynamic is found as one-tenth of Urgent Parent-Gynaecology pathways. Therefore, the pathway which needs to be focused on can be considered as the parent gynaecology. Another important finding is that the number of patients waiting for a follow-up appointment decreases while the time periods of the follow-up appointment increases, in general. So, the system can be made more efficient by solving bottlenecks in the time periods of the follow-up appointment which is less than 1 month. On the other hand, the number of patients who went out of system (defined as `other`) because of some reasons such as "did not attend (more than once)" is nearly half of the discharged patient number. It can be said that making the system more efficient can decrease the number of patients who went out of system. However, this situation may exceed the system capacity and it may be the reason of other bottlenecks. Therefore, the potential effects of a more efficient system should be examined in detail. Another important outcome is that the inpatient day case rate which can be defined as the weight of inpatient day case activities in inpatient activities is less than one in Gynae-Oncology pathway in contrast to others. Therefore, this information should be considered when evaluating the strategies which are related with inpatient treatment.

Another significant finding of this study is that the Gynaecology department mostly meets Referral to Treatment (RTT) targets especially for non-Routine pathways according to new outpatient appointment waiting times. However, the waiting time for follow-up appointments are longer than planned waiting time because of 'delays'. The amount of delays in a follow-up time period inform the demand on the time period and efficiency of the system. Therefore, finding out delays are one of the aims of this study. It can be said that the 'less than 1 month' follow-up time period in Urgent pathway is the busiest follow-up time period of the department. As it is known, the treatment processes for Urgent patients is applied in a shorter time. Therefore, follow-up

appointments for Urgent patients are booked mostly in 1 month. Considering most Parent-Gynaecology patients follow the Urgent pathway, finding the busiest time period as Urgent pathway- 'less than 1 month' is not surprising. However, it should be underlined that there is a significant delay in this time period though it is still in targeted time. This is because the total waiting time (sum of average pause and delay) for this follow-up time period is less than 4 weeks. Nevertheless, eliminating this delay is seen as an issue to improve the efficiency of the system due to its other potential effects on the system. Therefore, scenarios are tested and tried to eliminate all delays in the system.

At the first version of the first scenario, a clinic which serves only new outpatients of Urgent and Routine Parent-Gynaecology was added in the model. Although this scenario was enabled to decrease new outpatient waiting times, it dramatically increased the delays especially for busy follow-up appointment time periods and it congested the system. This is because this scenario was caused to be exceeded by the follow-up capacity. Therefore, a clinic which serves for new and follow-up Parent-Gynaecology patients were added at the second version of the first scenario in order to solve the follow-up overcapacity problem and it has been found that both new outpatient waiting times and follow-up delays have considerably decreased. Consequently, it can be said that adding a clinic for new outpatients needs to be balanced with an additional follow-up clinic or a clinic which is added to system should be served for both new and follow-up Parent-Gynaecology patients to improve the system.

Treatment durations are found as the one of the most focused factor in literature. For this reason, treatment durations were changed in scenario two. At the first version of the scenario two, the 'perfect model' were tested so, new and follow-up outpatient appointment time slots were reduced respectively to 15 and 10 minutes. As a result of this scenario, all congestions were solved, the waiting times and delays decreased and the system became very effective. It is clear that this kind of certain decrease in treatment durations cannot be applied in the real system. However, this scenario enabled to understand the importance of treatment durations. Consequently, some strategies can be followed to decrease the time of treatment related processes such as paper works or accepting patients. Additionally, the clinical procedure which needs shorter follow-up treatment duration (decided as 12 minutes) in Routine pathway was

considered in the second version of the second scenario as an applicable scenario in the current situation. Even this small changing in treatment duration helped to eliminate follow-up delays in the Routine pathway. However, it did not affect the other waiting times and delays as it is expected.

At the third scenario, the importance of virtual review clinics was examined by shifting some clinics as virtual review clinics. Due to the treatment duration of virtual review clinics (which are shorter than others), they significantly decreased delays in all pathways. Moreover, not only they declined follow-up delays, but also it affected waiting times for new outpatient appointments in Gynae-Oncology and Urodynamic pathways. The reason of this situation is that resources (clinics) in Gynae-Oncology and Urodynamic pathways were shared based on the volume of appointments instead of sharing the resources according to the new or the follow-up appointments. Thus, it can be deduced that the effect of this scenario is more than observed because there is no certain distribution in clinics in the real system. Therefore, virtual review clinics will benefit more than expected.

Finally, the effect of a nurse led clinic which accepts follow-up patients was examined in the fourth scenario. At the first version, the ideal (maximum) running situation (which is 5 days in a week) was tested as a perfect model and it has been found that all follow-up delays and waiting times for the new outpatient appointment in both Gynae-Oncology and Urodynamic declined similar to scenario three. However, scenario three indicated a better performance in terms of decreasing the 'less than 1 month' follow-up appointment delay in an Urgent pathway. But similar to scenario three, it can be said that the nurse led clinic will be very useful to cope up with delays. Moreover, the minimum running situation which is 1 day in a week was tested as a second version of the fourth scenario and it has been seen that it did not affect the delays too much when compared with others. However, this outcome gives information about the effect and the utilisation of the nurse led clinic. Thus, it can be interpreted that the nurse led clinic which is added to system should run more than 1 day in a week to eliminate delays.

Consequently, all scenarios facilitated to improve the current system, though decreasing treatment durations (scenario 2.1) was the best scenario according to the results. However, this scenario was performed to illustrate the perfect situation as it

cannot be appropriately applied in the real system due to a variety of illnesses, procedures and cases. On the other hand, shifting some clinics as virtual review clinics (scenario 3) was determined as the most feasible scenario in terms of eliminating follow-up appointment delays in the Gynaecology department. Additionally, one of the best scenarios to shorten the waiting times of new outpatients was (scenario 1) adding an extra one clinic to system. Therefore, these scenarios can be combined with each other in order to cope with delays and long waiting times.

It is important to also mention the limitations of this study. The one limitation is that the number of running clinics is seen very changeable in the determined time period (1.5 year) and there is no certain information (expectation) or data which provides clear clinic numbers without many correcting needs on the data and model such as sharing resources (clinics) between follow-ups and new outpatients. Therefore, attaining the accurate number of running clinics may present better results. Another limitation is that the D&T dataset was attained from a different database, so comparing D&T and another data such as outpatient activity in different stages requires complex data combining processes which may negatively affect the verification of the model. Because of this reason, the number of patients who visit D&T and waiting times for D&T procedures could not be calculated for each step of the patient pathways.

7.CONCLUSION

7.1. Conclusion

In this study, modelling the flow of patients thorough the steps in elective pathway was aimed in order to predict the demand for the Gynaecology department in the Cardiff &Vale University Health Board. For this purpose, the discrete event simulation model was used in the present study. The literature was reviewed and case studies were examined to provide base evidence to study. The modelling process was applied in two stages which were the data analysis and the simulation-model building. At the first step of the data analysis, the data was identified and prepared to use by applying some data mining and data grouping techniques. At the second step, descriptive statistics were attained and patient distributions and tables which show transitions between stages in the model were prepared. In addition, some useful extra statistics which were not used in the modelling process was presented to understand main demand features. In the simulation-model building stage, a discrete event simulation model was built by using the Simul8 software. The model consisted of four main patient pathways which are Uro-dynamics, Gynaecology Oncology, Urgent Parent Gynaecology and Routine Parent Gynaecology pathways. One of the most powerful side of this model is that the follow-up appointment time periods and the follow-up appointment numbers were integrated in the model and this provided to analyse follow-ups in detail. A lot of tests were made in the verification and the validation steps and it is decided that the model which enables to reveal the demand and waiting times at each stage of the pathways successfully presented the real system.

As a result of the simulation model, it has been found that more than 17,000 patients come to Gynaecology department in a year and most of them follow the Urgent Parent Gynaecology pathway. Moreover, the department in general meets new outpatient waiting time targets especially for non-Routine pathways. However, delays are found in follow-up appointments and it causes longer waiting times for follow-up appointments. Especially, the ‘less than 1 month’ follow-up time period in Urgent pathway is found as the busiest follow-up time period of the department.

After modelling the patient flow and finding out demand and bottlenecks in the system, the main four scenarios (adding an extra clinic, decreasing treatment duration, shifting some clinics as virtual review clinics and adding a nurse led clinic) were

tested. It has been found that all scenarios have improved the current system, but decreasing all treatment durations was defined as the best scenario. On the other hand, shifting some clinics as virtual review clinics was determined as the most feasible scenario to eliminate delays in follow-up appointments and adding an extra clinic to system was found as one of the best scenarios to decrease new outpatients waiting times. Therefore, scenarios can be mixed with each other to solve different problems.

Consequently, the developed model can be used as a tool which allows to explore the different situations. Therefore, the model helps the service manager to set a course for the department and to cope with delays and long waiting times. Furthermore, the study illustrates the bottlenecks and patient flows in an elective pathway model which is rarely seen in literature.

7.2. Future works

It can be mentioned about some potential areas to extend the scope of this study. Firstly, the sub-system which was built to view the follow-up appointments can be developed by studying on backlogs of each follow-up time period appointment in each pathway. Moreover, the interaction between the follow-up appointment time periods and the follow-up appointment numbers can be improved by adding backlogs and examining distributions in detail e.g. finding distributions of applied treatment and procedures in each follow-up appointment.

Another study can focus on finding accurate running clinic numbers by using more complex data mining and statistic methods. This kind of study can also be extended by using optimisation techniques, hence an optimized clinic schedule can be developed and integrated with the model. Consequently, the resources of the model can be improved by optimising resource schedules and defining different types of clinics such as a pre-operation, consultant led activity or emergency.

In addition, another future research can be made to fully integrate D&T to the model. Therefore, the demand on D&T at each step in patient pathway can be found and more accurate and detailed results about the patients who visit D&T can be attained.

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APPENDIX 1

Results of The Model Contributing Data Analysis

The rate of patients who attended their outpatient appointment is called “attendance ratio” and the rate of patients who did not attend their outpatient appointment is shortly called “DNA ratio” in the rest of the section.

cFirstly, the attendance ratio for each pathway which forms the fundamental Gynaecology pathway is examined. Figure 1 shows that Gynae-Oncology pathway has the highest patient attendance ratio with 93.75 percent and the attendance ratio of parent-gynaecology pathway is seen as 90.51 percent. However, urodynamic pathway has the highest DNA ratio with 22.75.

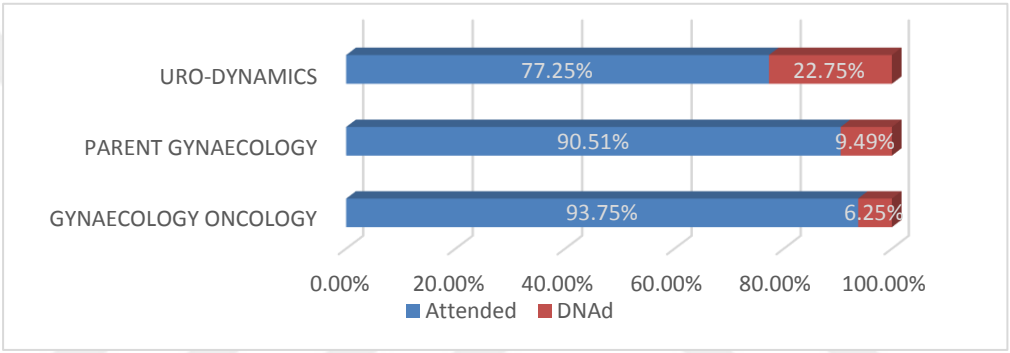


Figure 1 Treatment Speciality and Referral Status

One of the most significant patient characteristics may be considered as the age of patient, because age is one of the important factors on treatment method and healthcare strategy. Therefore, patient age is analysed and results are illustrated in Figure 2 as the frequency of patient age. It is seen that patient who is referred to Gynaecology department are mostly between 22 and 31 ages.

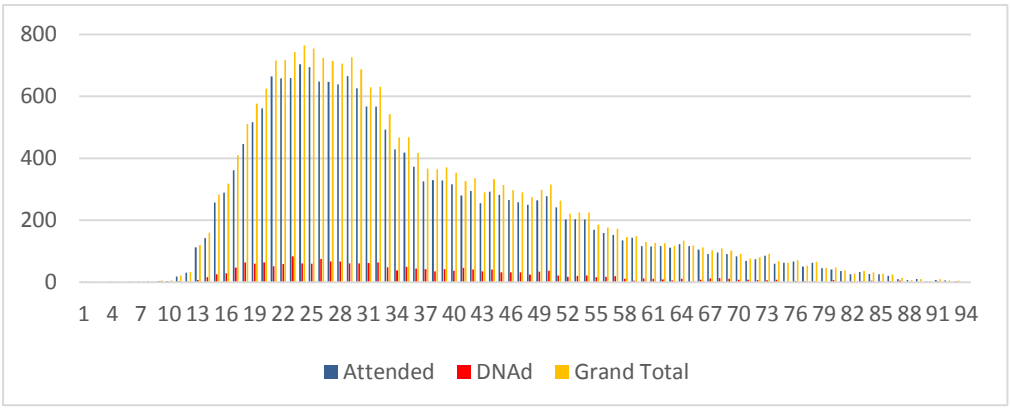


Figure 2 Age and Referral Status

The effect of elderly on the attendance to hospital appointment is often wondered and investigated when developing healthcare policies and it is generally expected that age

is an important factor on DNA ratio. However, it is seen in Figure 2 that the distribution of the number of "Did not Attend" patients by age shows similar feature with the distribution of the number of "Attended" patients and the highest "Did not Attend" count is found between 22 and 31 ages. Moreover, when Figure 2 evaluated in detail, it can be seen that the DNA ratio remain stable. Therefore, it might be interpreted that the age of the patient is not a main effective factor on the attendance of patient to the hospital appointment.

Another factor which can be considered important on DNA ratio is duration between referral and treatment. This duration can be explained as the time that patient take place in the outpatient waiting list. According to Figure 3, most of the patients wait approximately one month for treatment after referral.

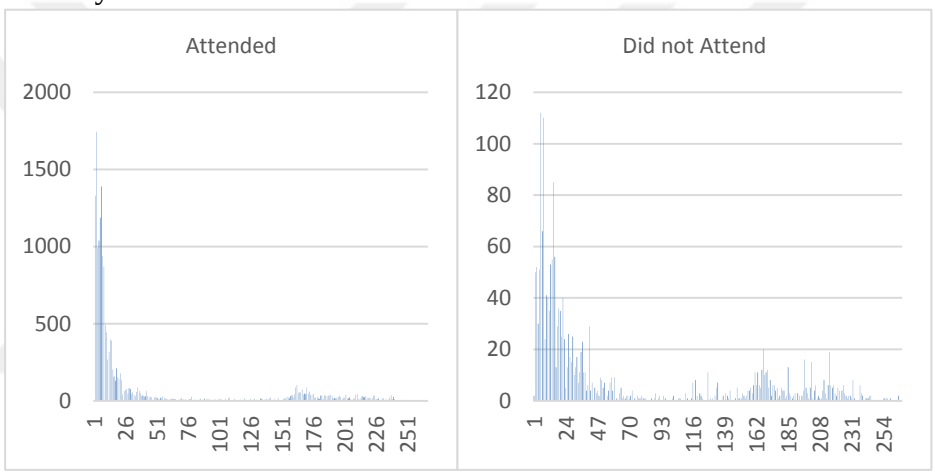


Figure 3 Days Wait and Referral Status

The relationship between days-wait and attendance status of patients can be observed in Figure 3. As it is seen, the shapes and features of graphs are quite similar; however, the frequency of "Did Not Attend" after waiting 150 days draws the attention with a slight rise. For a correct interpretation, the DNA ratio according to days wait should be examined as in Figure 4.

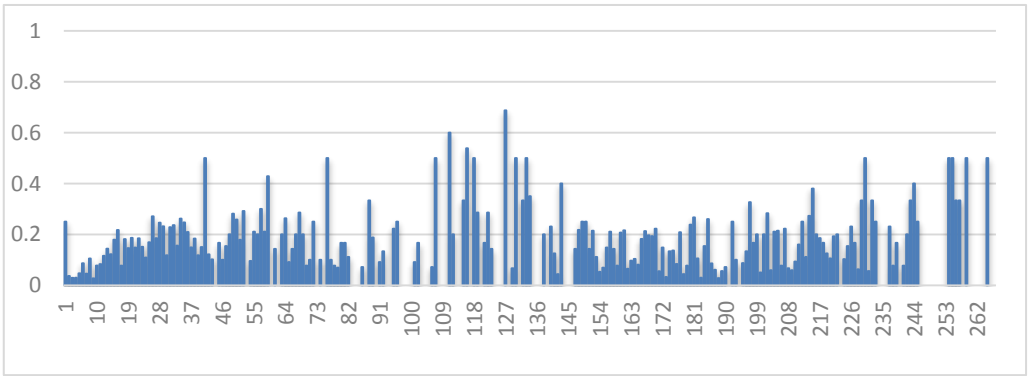


Figure 4 DNA ratio and Days wait

It can be comprehended by looking Figure 4 that the DNA ratio according to days wait is changeable and it does not have any trend. Consequently, the duration between referral and treatment does not have a significant impact on the patient attendance to outpatient appointment.

The booking related issues are also subject to understand the reasons for DNA ratio. Finding the highest DNA ratio on booking related subjects such as booked clinic subtype, booked period or booking type helps to the hospital and department administrators to improve booking policy.

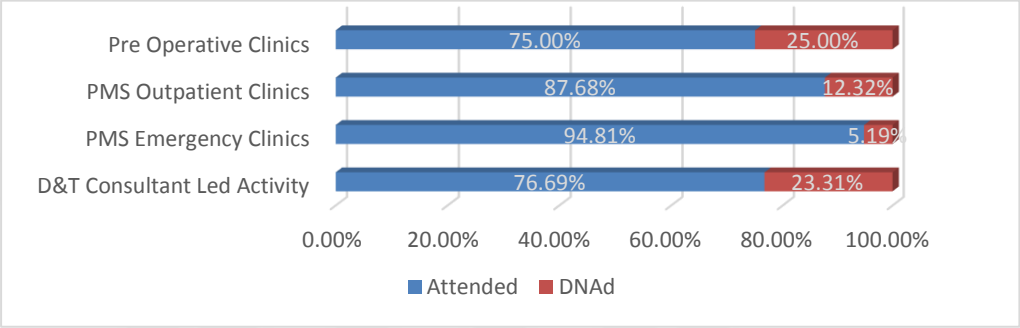


Figure 5 Booked clinic Sub Type and Referral Status

Figure 5 illustrates the DNA ratio of booked clinic subtypes. In this figure, it is clear that there is significant distinctness between booked clinic subtypes in terms of attendance and DNA ratios. Furthermore, the highest attendance ratio is seen in PMS Emergency Clinics with 94.81 percent while the Pre-Operative Clinics have the lowest attendance ratio with 75 percent. It means that the difference between DNA ratios of clinic subtypes reaches about 20 percent. Additionally, it is seen that PMS Outpatient Clinics approximately have the average DNA ratio of the sub clinics with 12.32 percent.

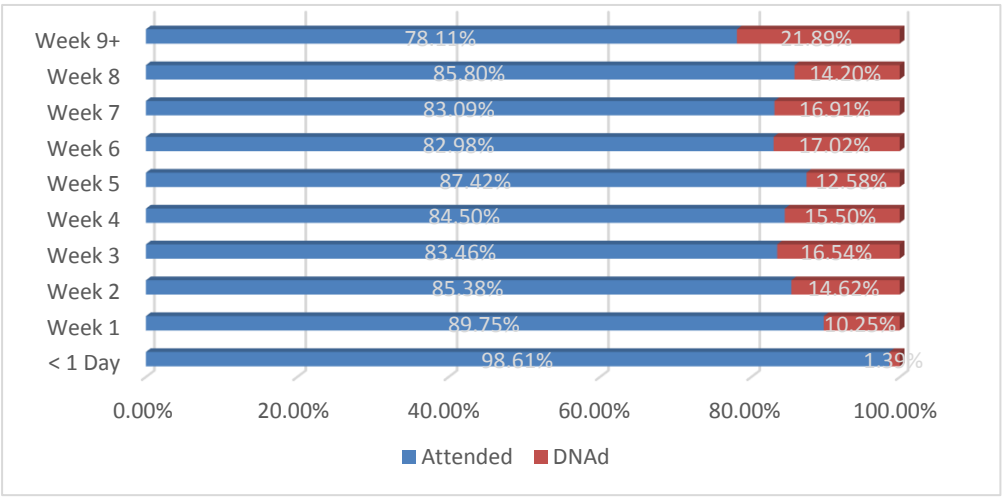


Figure 6 Booking time period and Referral Status

Booked period may be considered as another remarkable booking related factor which affects the patient attendance to hospital appointment. According to Figure 6, the DNA ratio relatively increases when the time of booked period widen, in general. For instance, while the highest DNA ratio is seen in more than 9-week bookings with 21.89 percent, the lowest DNA ratio is found in less than 1 day (emergency) bookings with 1.39 percent. In addition, it can be mentioned about a fluctuation between week 2 and week 8 in booked periods.

Booking type which informs about the way patient choose for booking is another important factor to find out DNA reasons. Due to this reason, the final analysis of model contributing data is done for this data and results are illustrated in Figure 7.

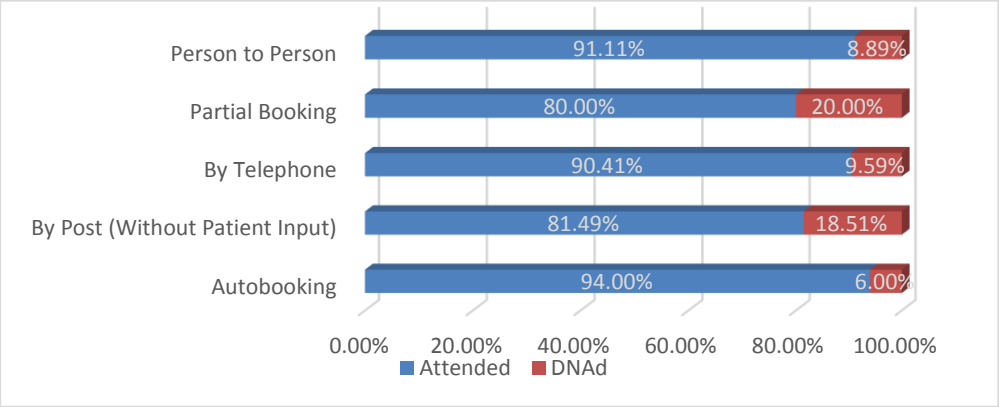


Figure 7 Booking Type and Referral Status

Auto booking has the greatest attendance ratio with 94 percent and person to person booking follows it with 91.11 percent attendance ratio. The DNA ratio of patients who booked by telephone is quite similar with person to person booking. The most attention-grabbing DNA ratios are seen in by post and partial booking. It is interesting that partial booking which is considered as a method that decreases DNA ratio has the highest DNA ratio with 20 percent. Consequently, it may be interpreted that booking type can be a distinguishing reason in terms of the ratio of patients who attend the appointment in Gynaecology department.

APPENDIX 2

The distribution of follow-up appointment time periods by follow-up appointment numbers:

	Follow up appointment time periods						
FU number	**TOTAL**	less than 1	between 1-3	between 3-6	between 6-9	between 9-12	more than 12
0	**21,73%**	12,63%	12,87%	19,70%	41,42%	72,22%	96,08%
1	**24,18%**	27,45%	22,12%	21,43%	32,22%	11,11%	1,96%
2	**19,22%**	22,44%	19,41%	20,35%	15,06%	5,56%	0,00%
3	**12,91%**	16,23%	14,22%	12,34%	7,11%	11,11%	1,96%
4	**8,59%**	8,82%	11,06%	10,82%	1,67%	0,00%	0,00%
5	**5,61%**	4,81%	8,35%	6,49%	2,09%	0,00%	0,00%
6	**3,62%**	3,61%	4,29%	5,19%	0,42%	0,00%	0,00%
7	**2,16%**	2,20%	3,84%	1,95%	0,00%	0,00%	0,00%
8	**0,93%**	0,80%	1,58%	1,08%	0,00%	0,00%	0,00%
9	**0,41%**	0,20%	1,13%	0,22%	0,00%	0,00%	0,00%
10	**0,35%**	0,40%	0,45%	0,43%	0,00%	0,00%	0,00%
11	**0,23%**	0,40%	0,45%	0,00%	0,00%	0,00%	0,00%
12	**0,06%**	0,00%	0,23%	0,00%	0,00%	0,00%	0,00%
13	**0,00%**	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
14	**0,00%**	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
15	**0,00%**	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
16	**0,00%**	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
17	**0,00%**	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
18	**0,00%**	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
19	**0,00%**	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
20	**0,00%**	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
21	**0,00%**	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
22	**0,00%**	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Grand Total	**100,00%**	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%

Table 1 The distribution of Gynae-oncology follow-up appointment time periods by follow-up appointment numbers

	Follow up appointment time periods						
FU number	**TOTAL**	less than 1	between 1-3	between 3-6	between 6-9	between 9-12	more than 12
0	**13,22%**	18,75%	5,00%	18,18%	42,86%	13,22%	18,75%
1	**30,58%**	31,25%	30,00%	27,27%	42,86%	30,58%	31,25%
2	**20,66%**	18,75%	16,67%	36,36%	14,29%	20,66%	18,75%
3	**12,40%**	9,38%	13,33%	18,18%	0,00%	12,40%	9,38%
4	**4,96%**	3,13%	8,33%	0,00%	0,00%	4,96%	3,13%
5	**5,79%**	3,13%	10,00%	0,00%	0,00%	5,79%	3,13%
6	**1,65%**	0,00%	3,33%	0,00%	0,00%	1,65%	0,00%
7	**2,48%**	3,13%	3,33%	0,00%	0,00%	2,48%	3,13%
8	**0,83%**	0,00%	1,67%	0,00%	0,00%	0,83%	0,00%
9	**1,65%**	0,00%	3,33%	0,00%	0,00%	1,65%	0,00%
10	**0,83%**	0,00%	1,67%	0,00%	0,00%	0,83%	0,00%
11	**0,00%**	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
12	**0,83%**	3,13%	0,00%	0,00%	0,00%	0,83%	3,13%
13	**0,83%**	3,13%	0,00%	0,00%	0,00%	0,83%	3,13%
14	**0,83%**	0,00%	1,67%	0,00%	0,00%	0,83%	0,00%
15	**0,00%**	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
16	**0,83%**	3,13%	0,00%	0,00%	0,00%	0,83%	3,13%
17	**0,00%**	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
18	**0,83%**	0,00%	1,67%	0,00%	0,00%	0,83%	0,00%
19	**0,00%**	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
20	**0,83%**	3,13%	0,00%	0,00%	0,00%	0,83%	3,13%
21	**0,00%**	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
22	**0,00%**	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Grand Total	**100,00%**	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%

Table 2 The distribution of Urodynamic follow-up appointment time periods by follow-up appointment numbers

	Follow up appointment time periods						
FU number	**TOTAL**	less than 1	between 1-3	between 3-6	between 6-9	between 9-12	more than 12
0	**27,06%**	10,81%	23,59%	27,99%	55,36%	68,18%	87,02%
1	**40,33%**	48,83%	37,10%	38,79%	33,33%	24,24%	9,16%
2	**16,39%**	19,24%	17,65%	18,15%	7,99%	5,30%	3,82%
3	**7,44%**	8,92%	8,66%	8,42%	2,47%	0,76%	0,00%
4	**3,79%**	4,35%	5,37%	4,21%	0,60%	0,00%	0,00%
5	**1,92%**	2,72%	2,65%	1,57%	0,17%	0,00%	0,00%
6	**1,17%**	1,74%	2,13%	0,41%	0,00%	1,52%	0,00%
7	**0,55%**	0,87%	0,84%	0,25%	0,09%	0,00%	0,00%
8	**0,41%**	0,76%	0,52%	0,15%	0,00%	0,00%	0,00%
9	**0,32%**	0,60%	0,45%	0,05%	0,00%	0,00%	0,00%
10	**0,16%**	0,34%	0,19%	0,00%	0,00%	0,00%	0,00%
11	**0,12%**	0,26%	0,13%	0,00%	0,00%	0,00%	0,00%
12	**0,11%**	0,23%	0,13%	0,00%	0,00%	0,00%	0,00%
13	**0,07%**	0,11%	0,13%	0,00%	0,00%	0,00%	0,00%
14	**0,04%**	0,08%	0,06%	0,00%	0,00%	0,00%	0,00%
15	**0,04%**	0,08%	0,06%	0,00%	0,00%	0,00%	0,00%
16	**0,01%**	0,04%	0,00%	0,00%	0,00%	0,00%	0,00%
17	**0,03%**	0,00%	0,13%	0,00%	0,00%	0,00%	0,00%
18	**0,01%**	0,00%	0,06%	0,00%	0,00%	0,00%	0,00%
19	**0,01%**	0,04%	0,00%	0,00%	0,00%	0,00%	0,00%
20	**0,00%**	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
21	**0,01%**	0,00%	0,06%	0,00%	0,00%	0,00%	0,00%
22	**0,01%**	0,00%	0,06%	0,00%	0,00%	0,00%	0,00%
Grand Total	**100,00%**	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%

Table 3 The distribution of Parent_gynae follow-up appointment time periods by follow-up appointment numbers

Screenshots of @RISK 7:

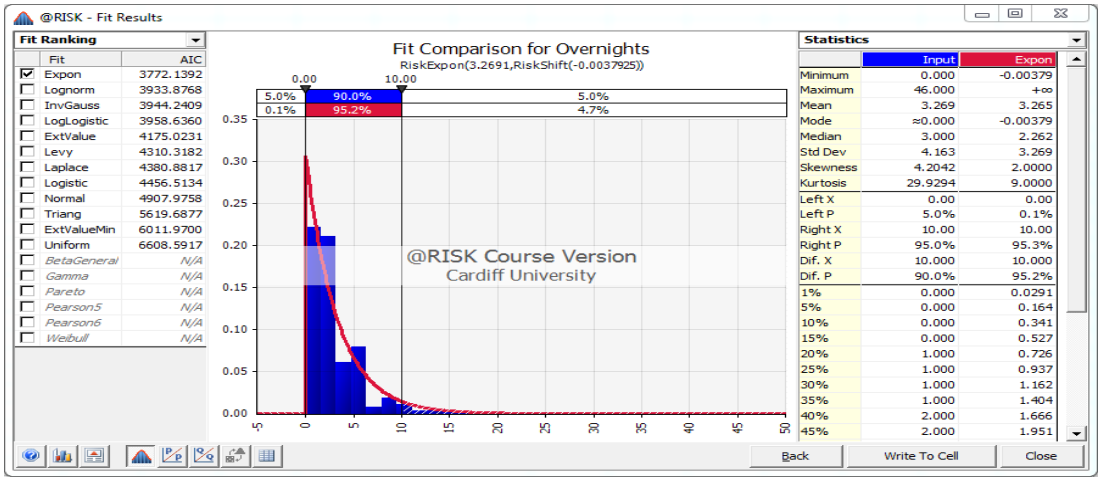


Figure 4 Screenshots of @RISK 7- The distribution of Gynae-Oncology "length of stay" data

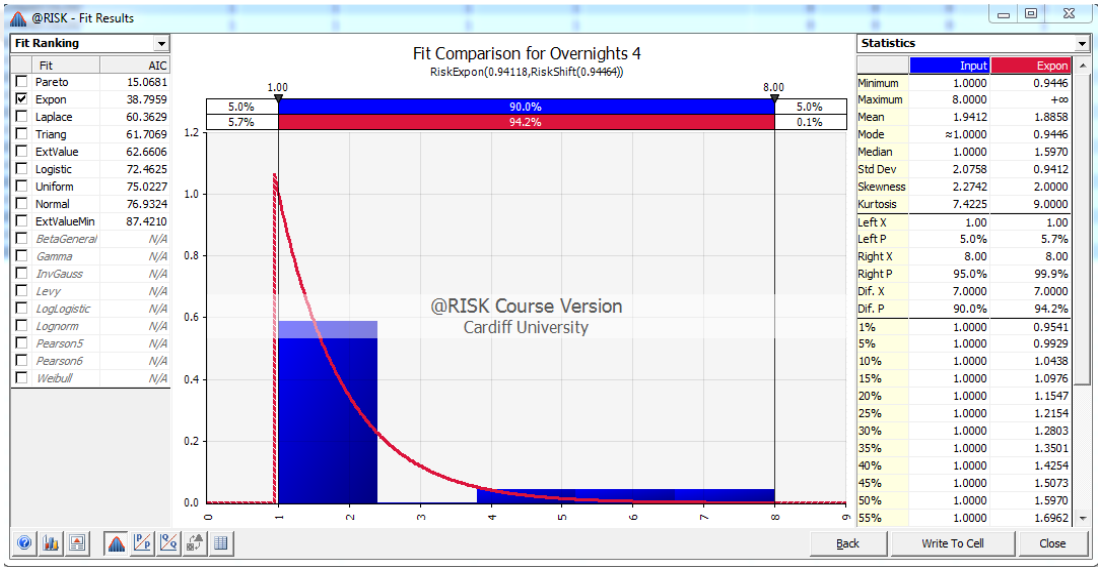


Figure 5 Screenshots of @RISK 7- The distribution of Urodynamic "length of stay" data

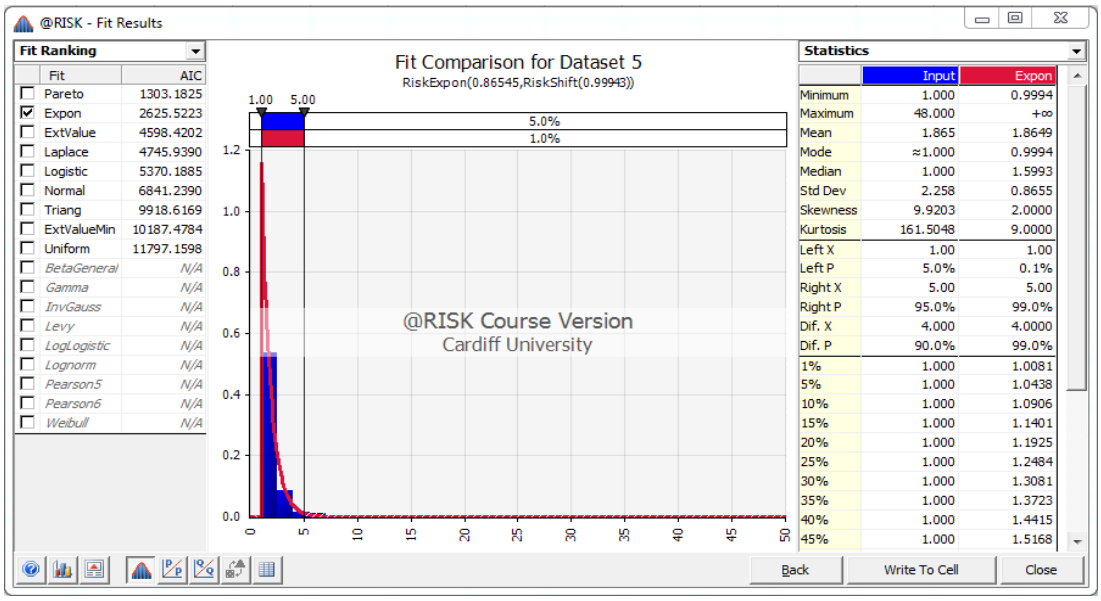
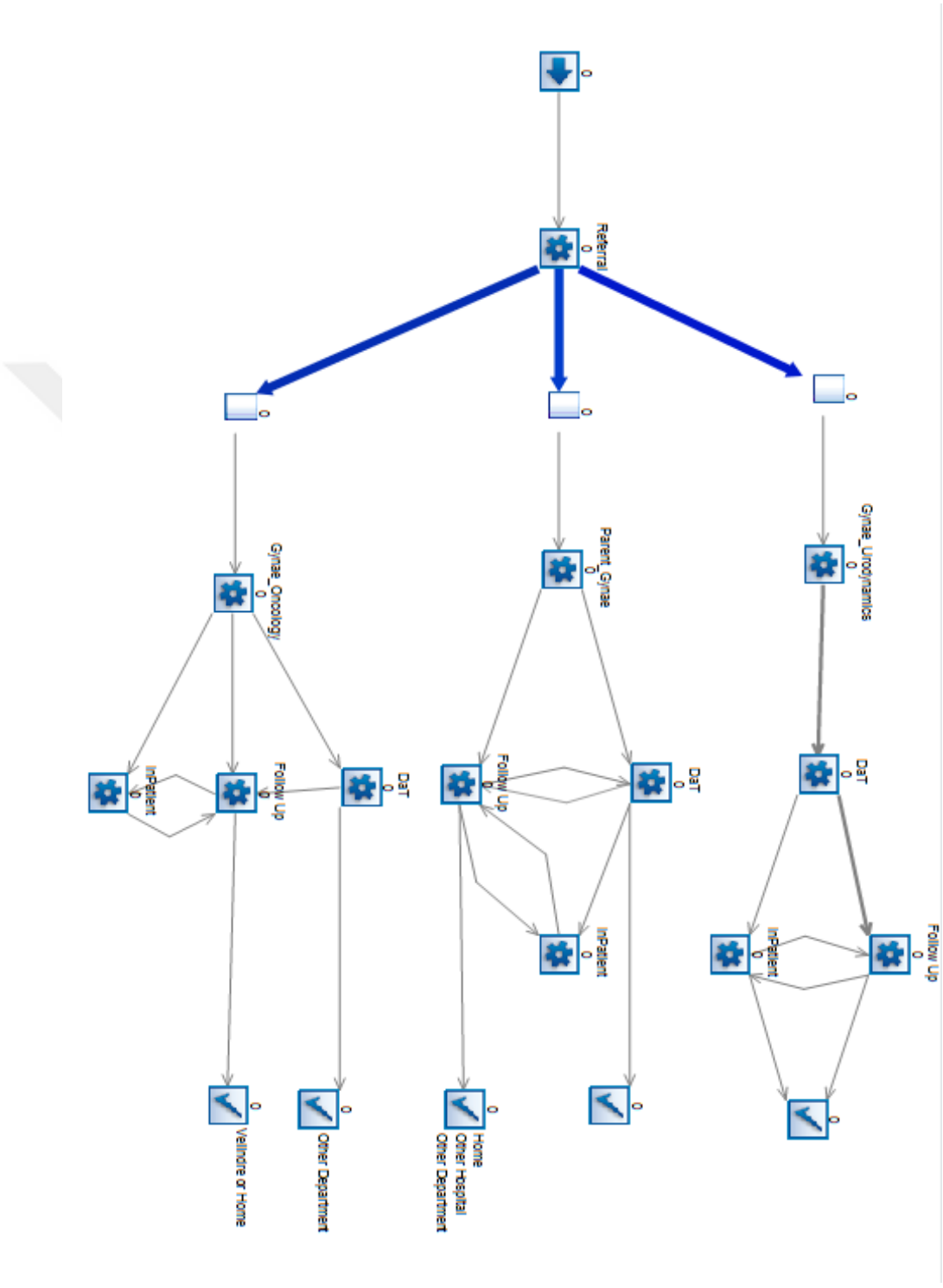


Figure 6 Screenshots of @RISK 7- The distribution of Parent-gynae "length of stay" data

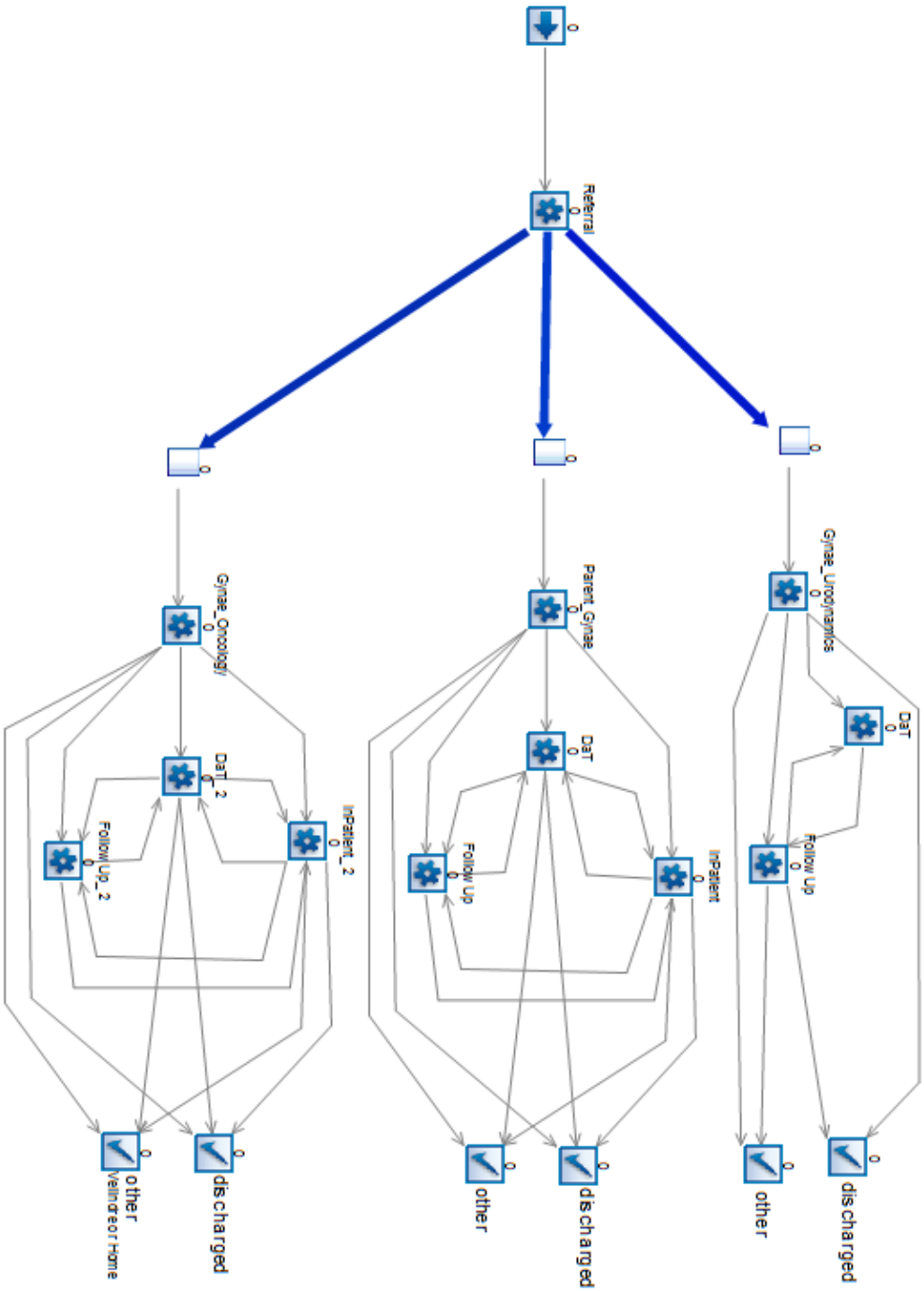
APPENDIX 3

Development of model:

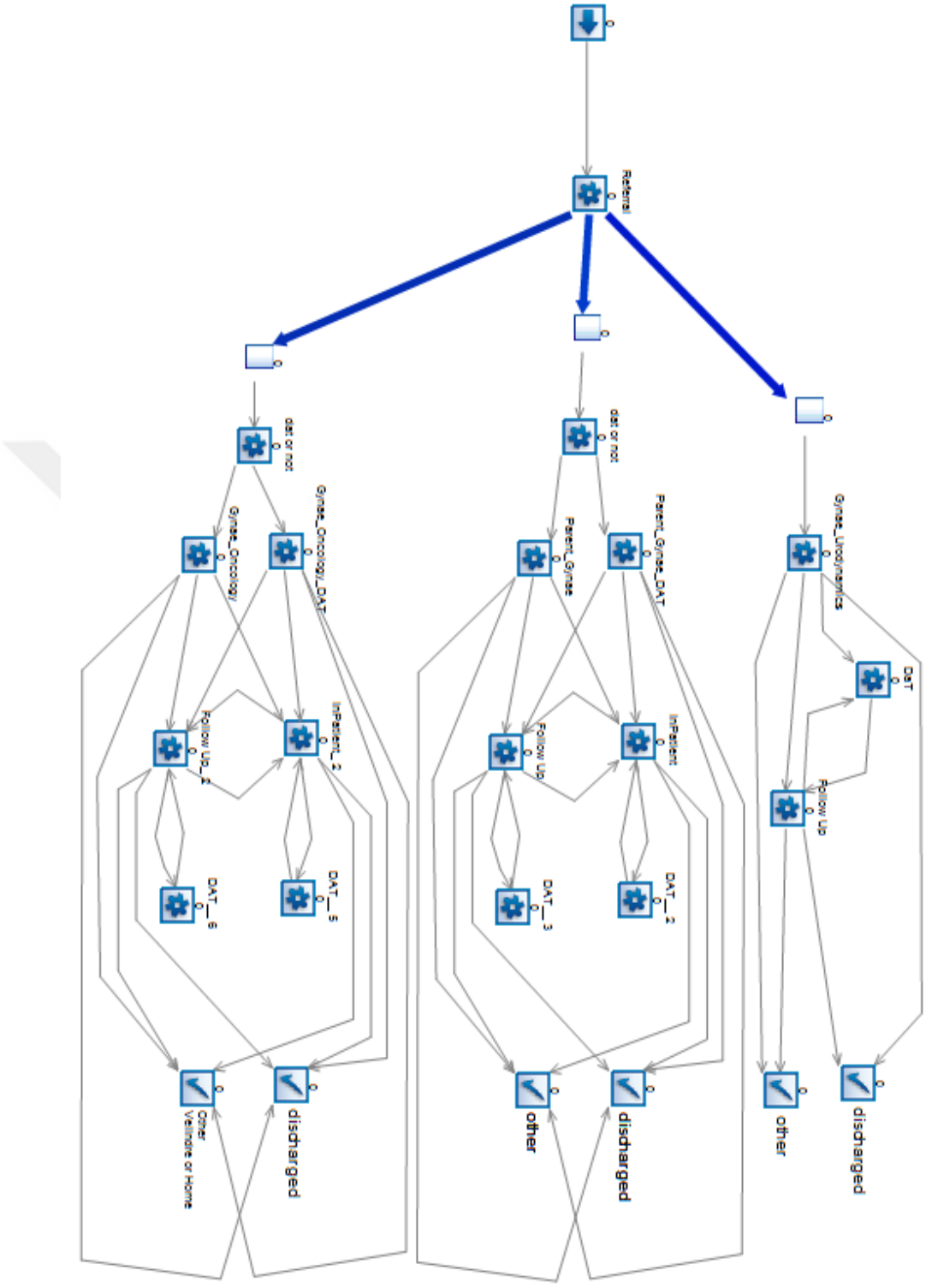
Model 1



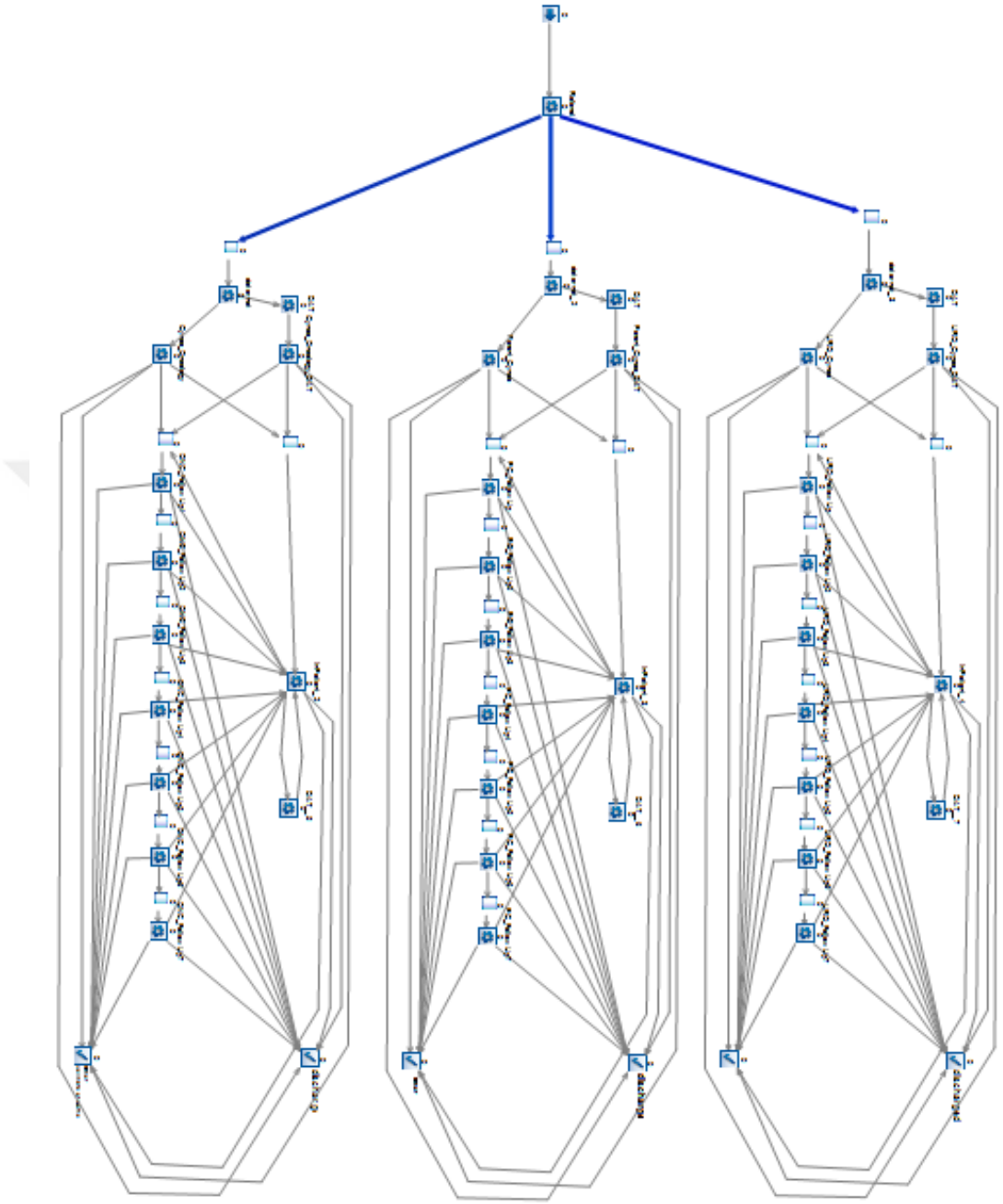
Model 2


Referral
Gynae_Oncology
DaT_2
Follow Up_2
InPatient_2
other
discharged
Parent_Gynae
DaT
Follow Up
InPatient
other
discharged
Gynae_Urodynamics
DaT
Follow Up
other
discharged

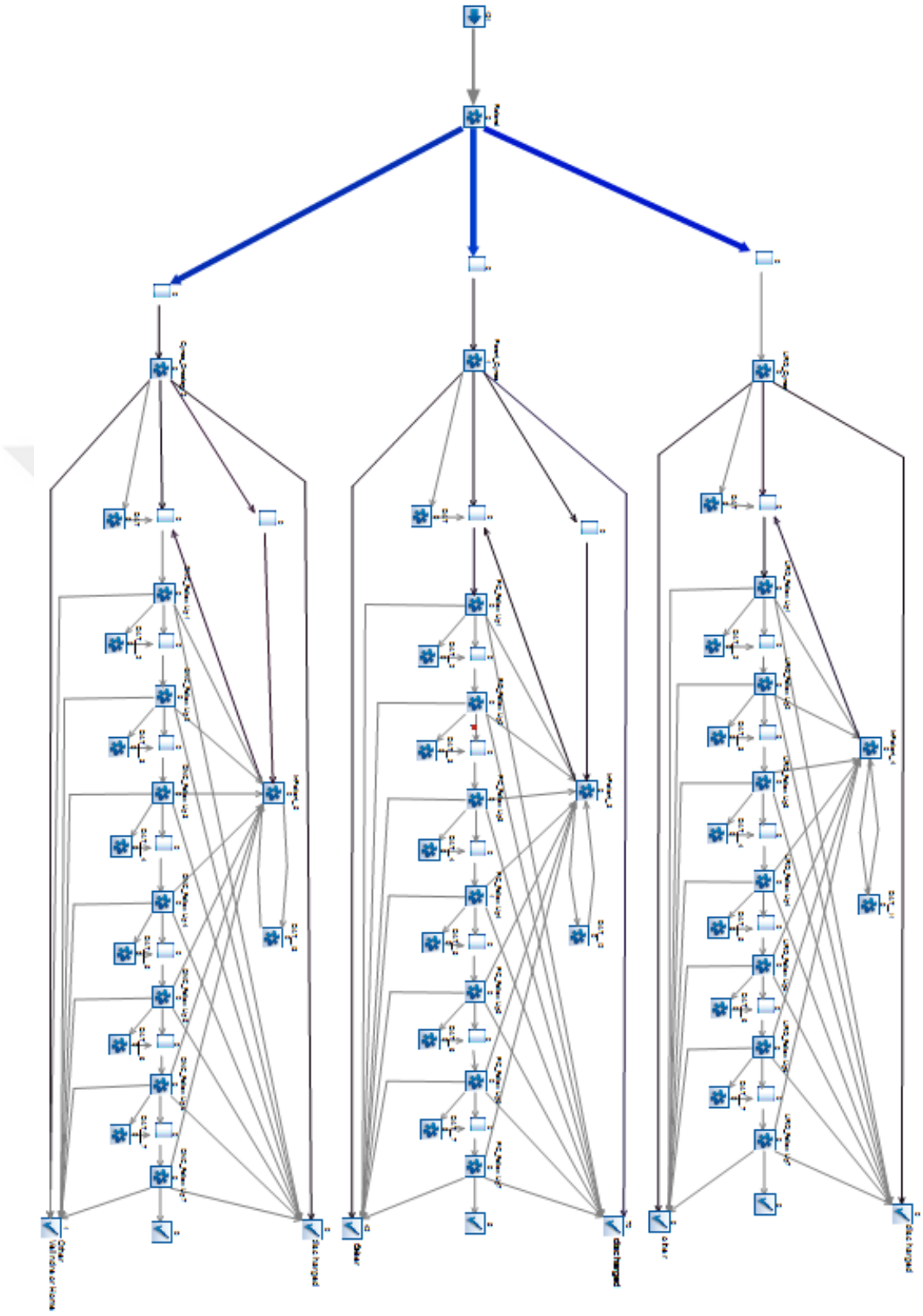
Model 3


Referral
dat or not
Gynäe_Oncology
Gynäe_Oncology_DAT
Follow Up_4
InPatient_2
DAT__6
DAT__5
Other
Velmate or Home
discharged
dat or not
Patient_Gynäe
Patient_Gynäe_DAT
Follow Up
InPatient
DAT__3
DAT__2
other
discharged
Gynäe_Urodynamics
DaT
Follow Up
other
discharged

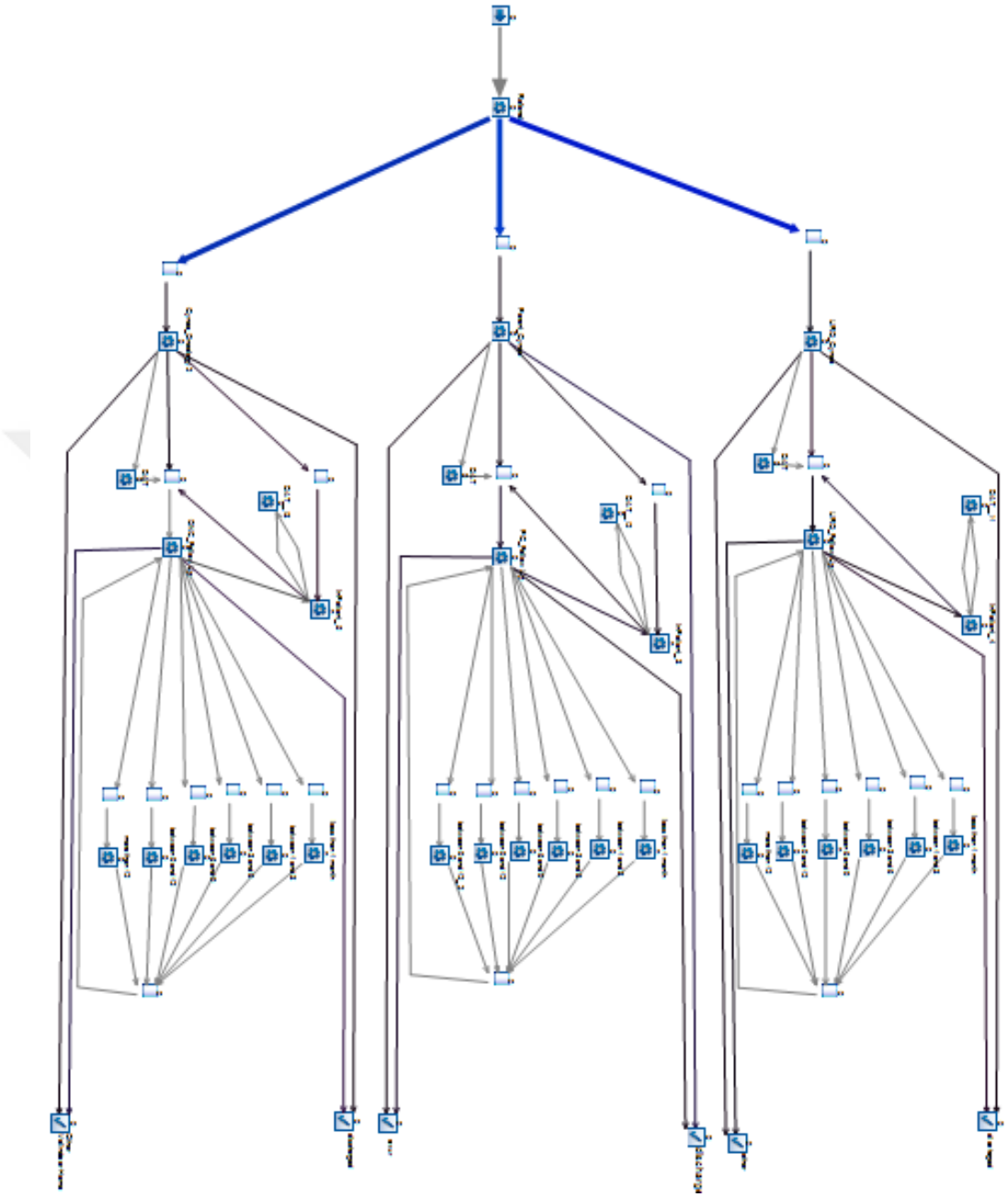
Model 4



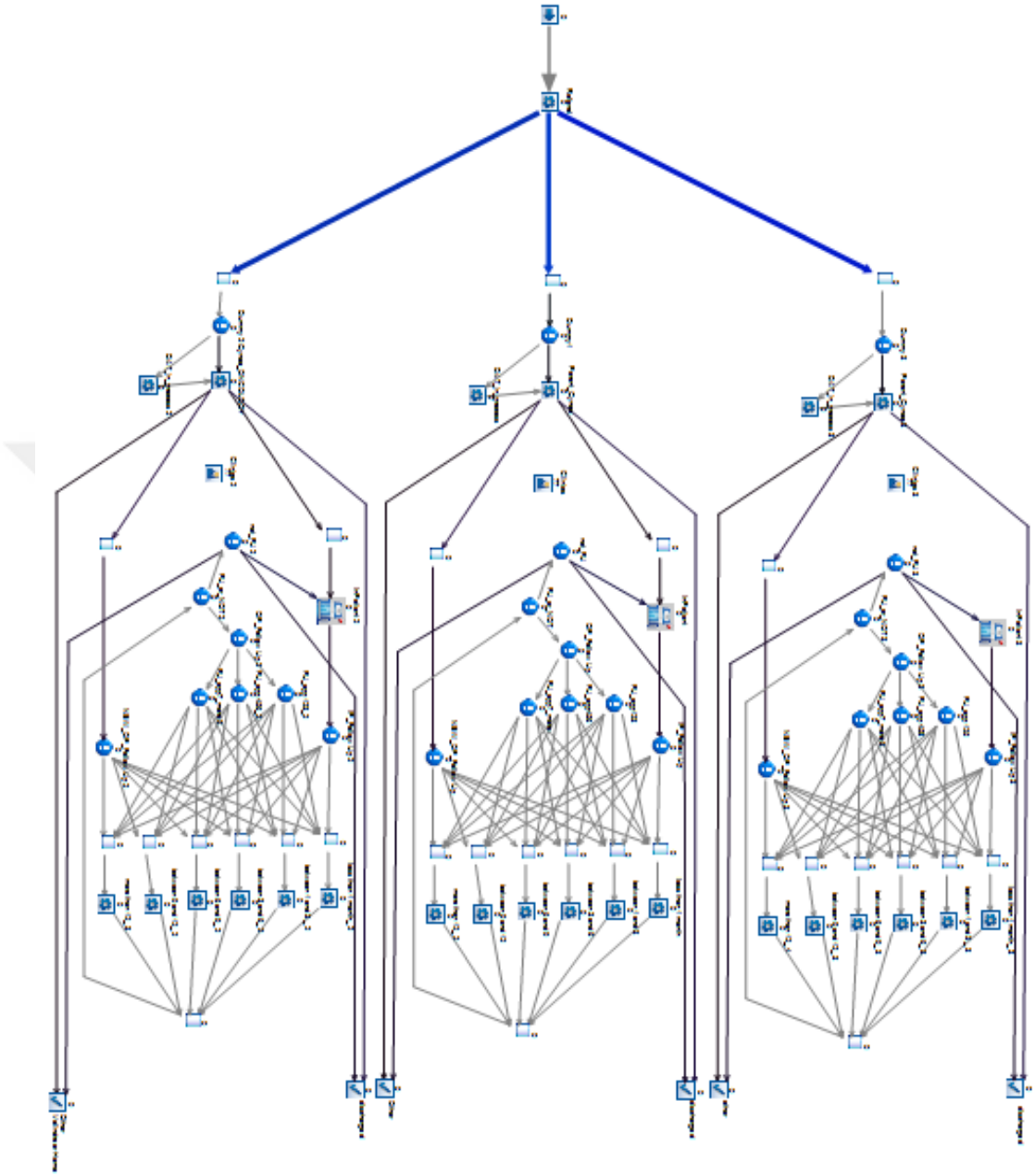
Model 5



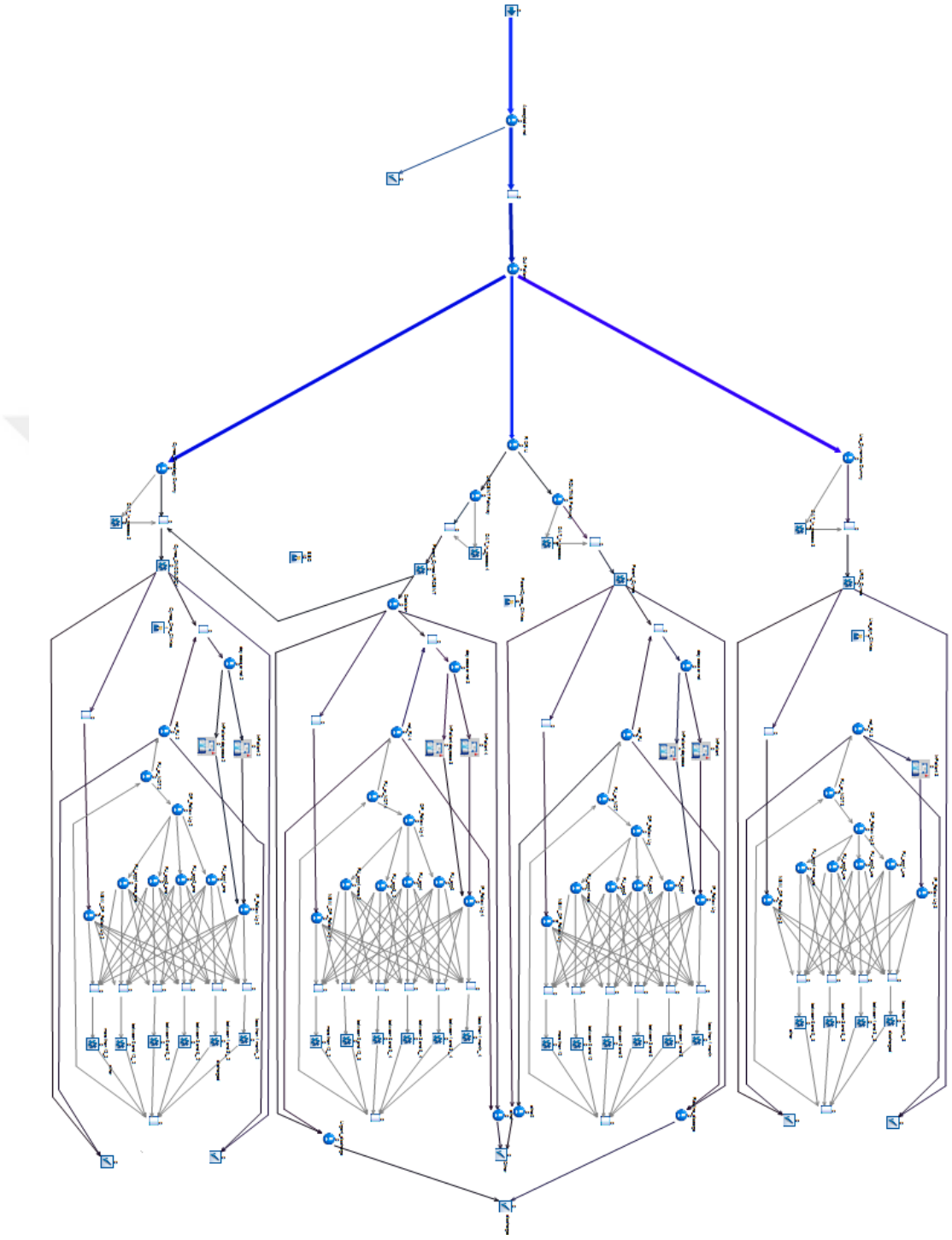
Model 6



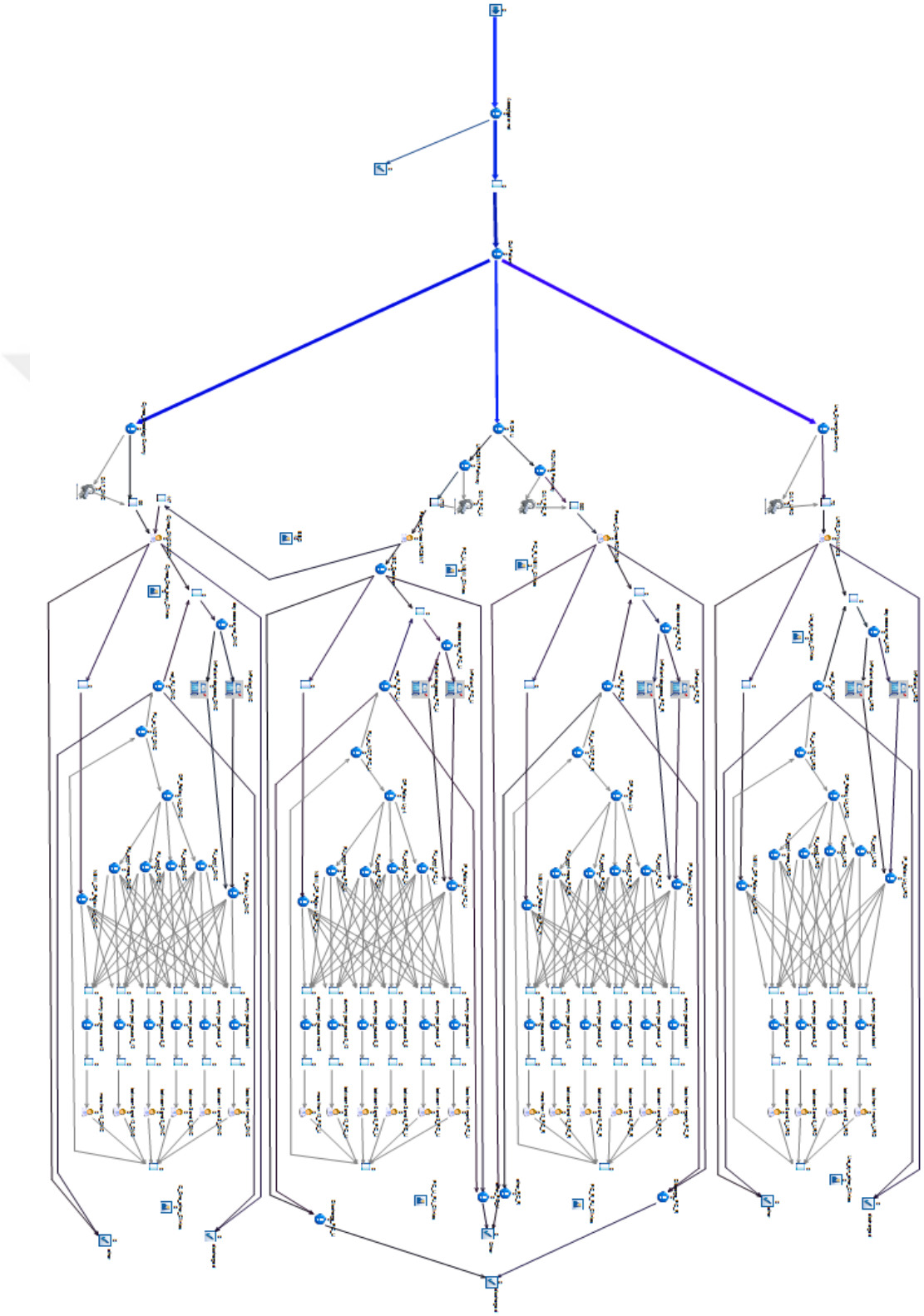
Model 7



Model 8

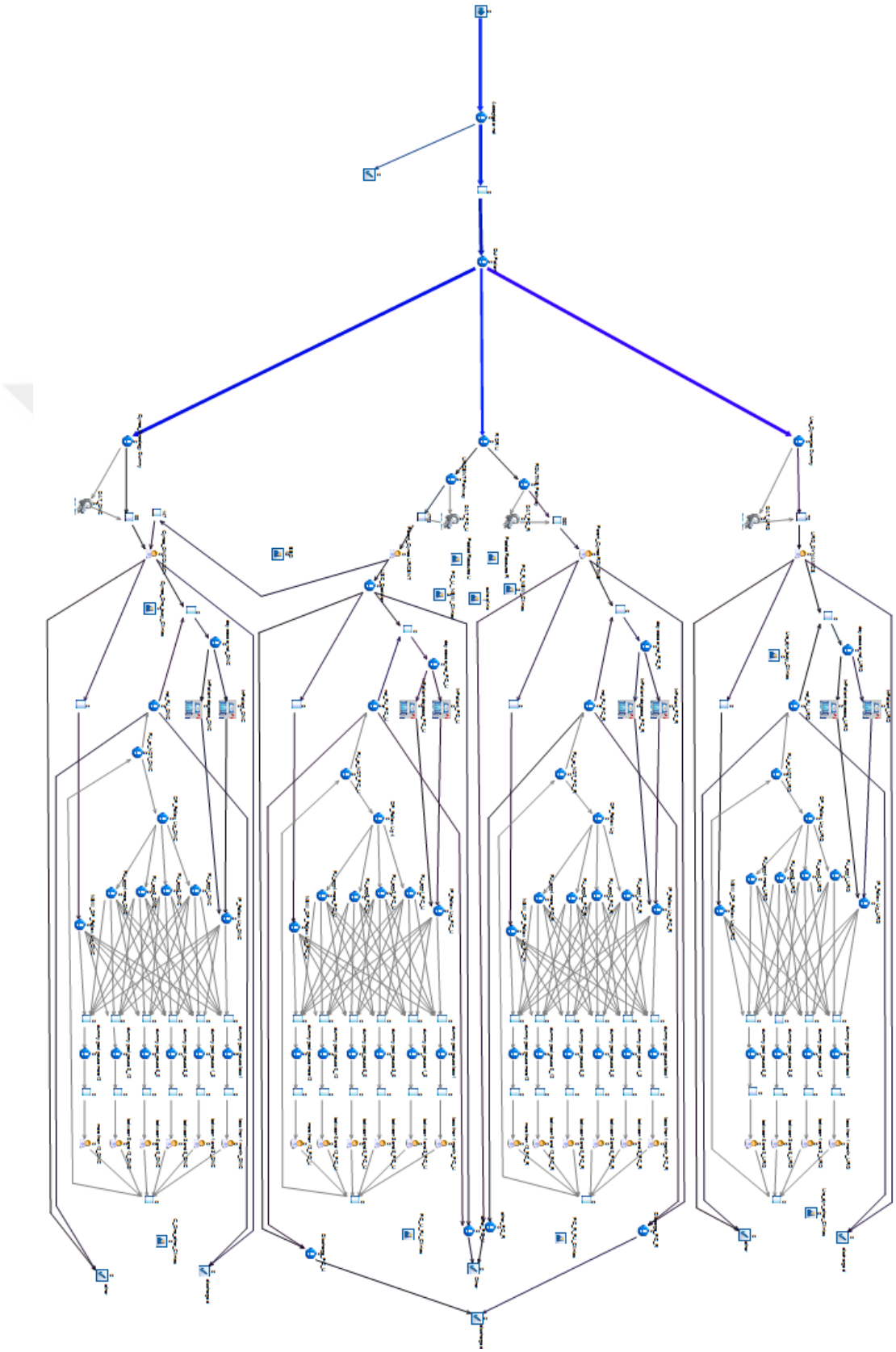


Model 9

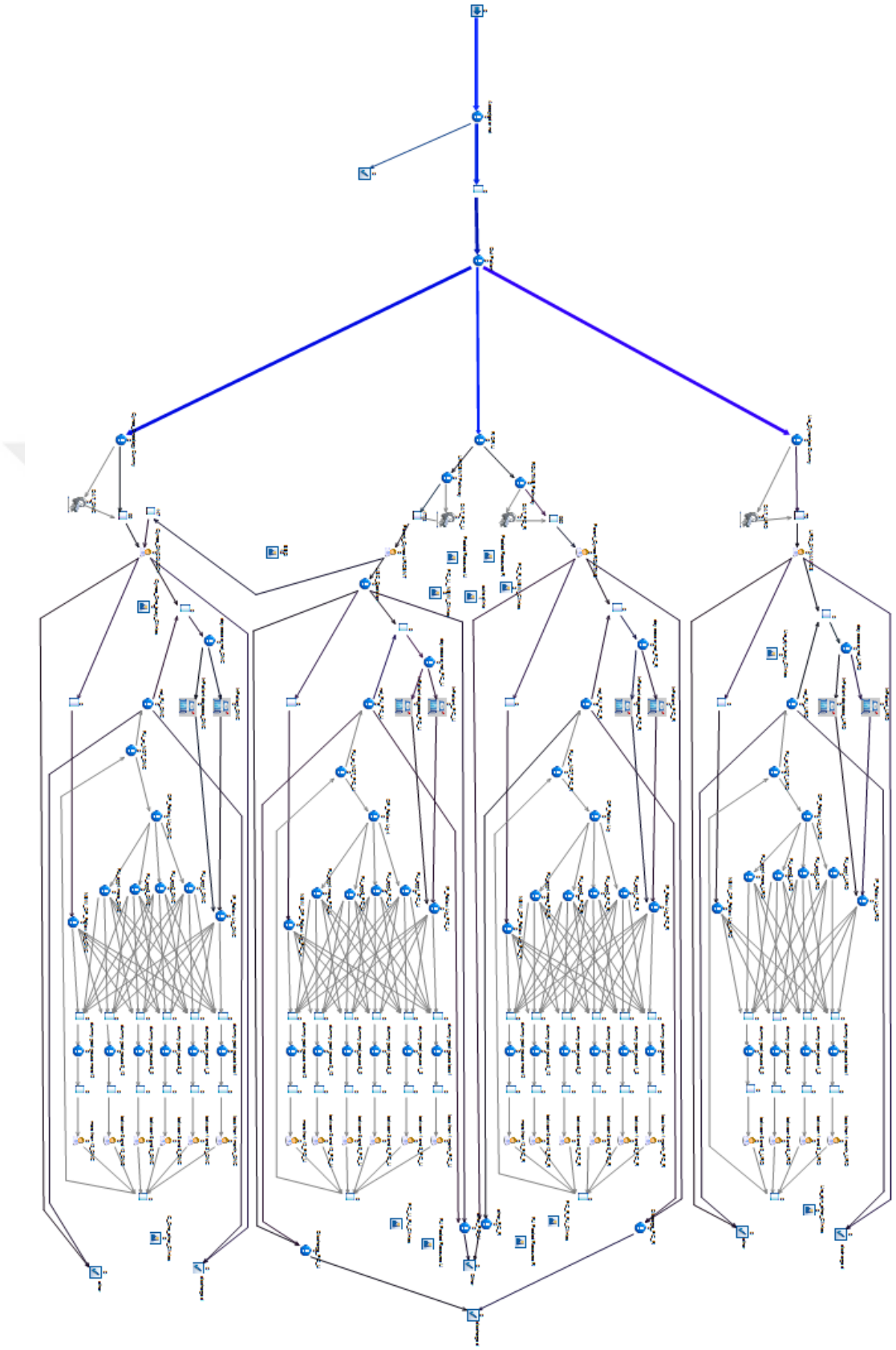


Scenarios:

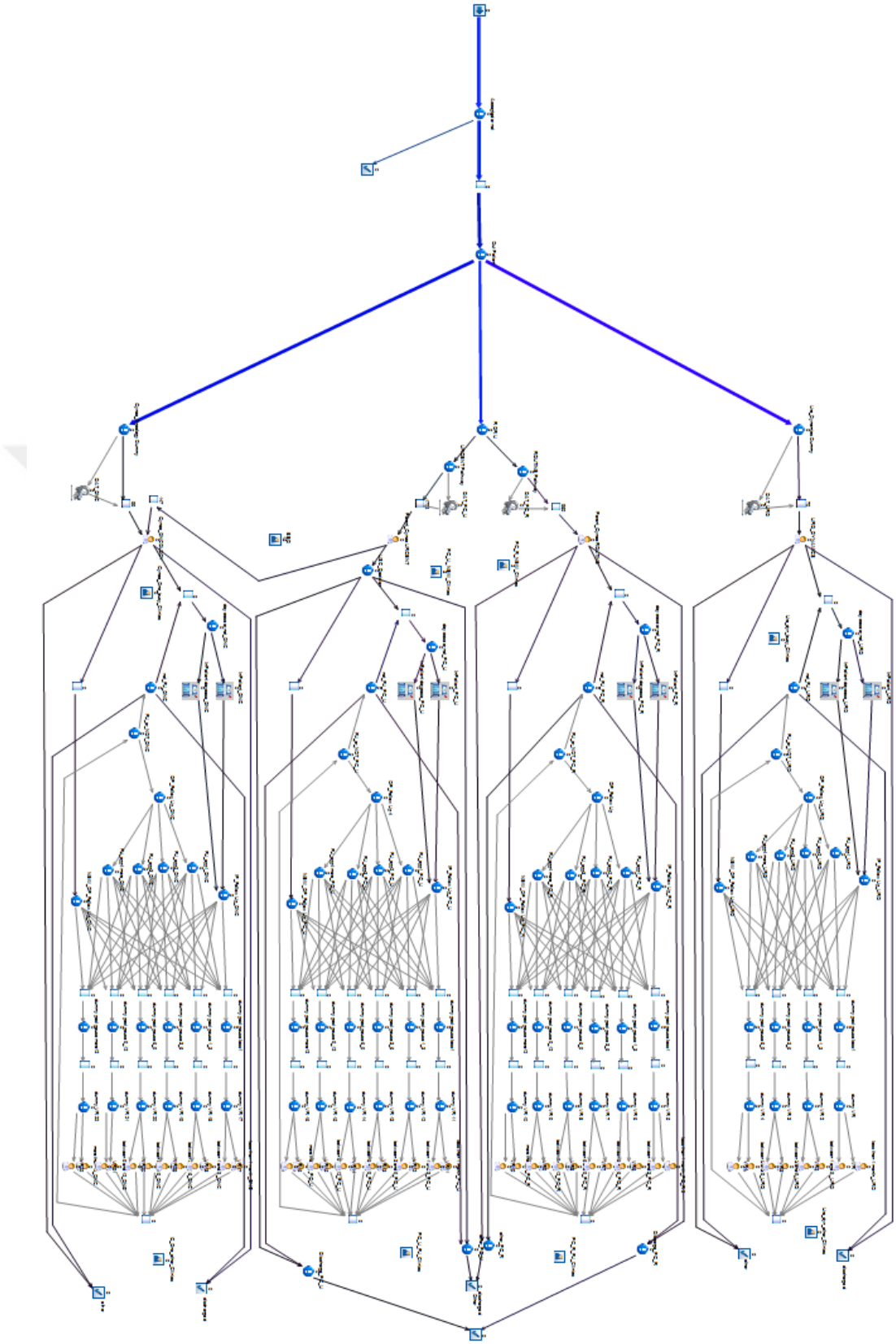
Model of Scenario 1.1



Model of Scenario 1.2



Model of Scenario 3



Model of Scenario 4.2