Modeling patient waiting times for an obesity service: a computer simulation study

Authors: Authors: Antuela A. Tako[1], Kathy Kotiadis[2], Christos Vasilakis[3], Alexander Miras[4], Carel W le Roux[4]

[1] School of Business and Economics, Loughborough University, LE11 3TU, UK
[2]Warwick Business School, University of Warwick, Coventry CV4 7AL, UK
[3] Clinical Operational Research Unit, University College London, London, WC1H 0BT, UK
[4] Imperial Weight Centre, Imperial College London, W6 8RF, UK

Abstract

Keywords: modeling, simulation, obesity, patient waiting times

Objective: To investigate the impact of alternative resource configurations on patient waiting times for obesity centers experiencing high referral rates.

Study design: We developed a computer simulation model of an obesity service in an Academic Health Science Centre (AHSC) providing lifestyle, pharmacotherapy and surgery treatment options for the UK's National Health Service (NHS).

Data collection: Model parameters on existing and projected demand and supply of treatments offered at an obesity service were collected.

Principal findings: Simulation results showed that the introduction of an additional surgeon improves patient waiting times for surgery. The addition of one physician reduces the waiting list for pharmacotherapy clinics, but without an additional surgeon, the surgical part of the pathway experiences long waiting times. Demand for the obesity treatments can be met by adding new resources, but also by managing demand for services and reducing referrals into the service. A phased implementation of resources was also modeled to guide decisions.

Conclusions: Simulation models can be used to identify resource configurations required to meet maximum waiting time targets from referral to treatment such as the UK's NHS 18 week target. This is achieved by considering a number of future scenarios.

Introduction

Obesity is a major concern in a number of countries worldwide (World Health Organisation 2011). In countries such as the United States of America (USA) and United Kingdom (UK), the current proportions of adults classified as obese are about

30% and 24% respectively, with increasing future forecasts double these proportions (Butland et al. 2007; Flegal et al. 2010).

Obesity is considered to be the primary cause of a number of diseases, such as diabetes, cardiovascular disease, hypertension and stroke and some types of cancer. A number of campaigns have been issued to tackle obesity from its roots, by monitoring population weight and nutrition through diet and exercise, however the present systems in most countries are considered inadequate (Swinburn et al. 2011). In the meantime, the clinical treatment of obesity has become a necessity and dedicated care services at physiological level have been established (Swinburn et al. 2011). However, the rise in obesity statistics poses a heavy burden on existing obesity care services, which are faced with the need to adapt to the increasing levels of demand for care.

The clinical treatment of obesity focuses on the reduction of body weight using three different options: a change in lifestyle, pharmacotherapy and bariatric surgery (also known as weight loss surgery). The first option involves a strict regime of diet, exercise and behavior change. The second option involves the management of weight loss drugs for a long term period. The final option consists of a more invasive intervention via surgery (National Institute for Health and Clinical Excellence, 2006). In the UK’s National Health Service, bariatric surgery usually refers to either three types of surgical interventions: gastric band, sleeve gastrectomy and gastric bypass. The choice of treatment is made based on patient preferences and health indicators such as the body mass index (BMI) or specific co-morbidities.

However, the ability to provide treatments is not enough to warrant referral in the UK with health service commissioners often choosing to support obesity centers that demonstrate good performance measured by performance indicators. Various targets have been set throughout the years for UK’s NHS institutions aimed at ensuring patients’ right to accessing services within a maximum waiting time. An important target that has received significant attention in the last 10-15 years is the18 week target. This target is calculated from patient referral to receipt of treatment (NHS Choices 2011; Department of Health 2010; Bowers 2009).

Existing studies on obesity use mathematical modeling to estimate obesity trends and healthcare expenditure for obesity-related diseases in the US and the UK (Gortmaker et al. 2011; Swinburn et al. 2011), but modeling of obesity services from an operational point of view considering patient waiting time targets has not be explored. Mathematical modeling of patient waiting times for obesity services poses difficulties for two main reasons. First, such systems do not fully comply with existing waiting time targets (NHS Choices 2011) because health services dealing with the clinical treatment of obesity often require to delay treatment, while the patient undergoes an initial weight loss program. This delay is clinically beneficial for the patient as it may improve the outcome of their treatment (NHS Choices 2011) but it needs to be accounted for. The calculation of the waiting time can be paused to account for the period of time required for weight loss to occur. However, the weight loss period itself is variable for each patient. Secondly, an inherent complexity is present due to varying patient waiting times (queuing time) for treatments, coupled with interlinked components, queues (waiting lists) and processes (clinics/treatments). This level of variability and complexity can be handled from an operational point of view using a simulation approach (Pitt 2008).

Different techniques of computer simulation have been used to model health care policy alternatives (Ringel et al. 2010), such as Monte Carlo simulation (Gilmer et al. 2007), agent-based simulation (Perlroth et al. 2010) and queuing models (Liu, and D'Aunno 2011). These models are mostly concerned with cost efficiencies of health insurance options. A simulation technique called Discrete Event Simulation (DES) is considered beneficial for modeling in the health context for a number of reasons (Pitt 2008). First, a visually interactive model showing a graphic representation of patients flowing through the system and the build-up of waiting lists is a distinctive feature of DES. It can help healthcare practitioners to visually understand how their service works. Furthermore, the obesity care service studied is complex by nature, with considerable variability due to a wide range of investigations and treatment options available to the patients and a multitude of health professionals required at different stages of the pathway (Butland et al. 2007). For this reason a simulation model is well positioned to deal with the variability of options available. Last but not least, in DES individual patients can be tracked based on their characteristics. This feature makes it possible to define the next treatment for a patient based on previously received ones and most importantly to measure and report on the time patients spend in the service, which is the main objective of this study.

In this study we describe a simulation study that evaluates the effect of organizational interventions on patient waiting times in a UK-based obesity service situated in an Academic Health Science Centre (AHSC) and providing care to the NHS, to inform the decisions made. We used DES models to explore the impact of alternative configurations of resources on the emerging waiting lists. The obesity service, which was designated as the first International Centre of Excellence for bariatric surgery by the Surgical Review Corporation and one of the preferred providers of bariatric surgery services for London and Northern Ireland, was experiencing high levels of demand for the treatment of obesity patients within their catchment. Although the results obtained are specific to the particular service, the findings could be useful to other similar centers within and outside the UK. The methods employed are transferrable to other obesity services. The next section describes the simulation model developed and the future scenarios defined.

Method

The simulation model

We built a DES model of the obesity care service, using the Simul8 software, developed by Simul8 Corporation. Our objective was to identify the impact of capacity changes in resources (namely surgeons and physicians) and patient referrals on patient waiting times.

The model represents the patient journey managed by the obesity service, starting from referral to treatment. A summary of the model parameters and logic is provided in Table 1. A brief description of the model follows.

Table 1 goes here

Patients are referred to the obesity service either from other secondary care services (due to suffering from serious co-morbidities of obesity) or from primary care services, i.e. general practitioners. An induction session is organized once a week, with up to 20 patients, where members of the team (physician, surgeon and nurses) explain treatment options. Patients are asked to complete a questionnaire with details of their health conditions and treatment preferences. The questionnaires are screened on the next day by a nurse referring patients to one of the following three outpatient clinics: lifestyle, pharmacotherapy or eligibility for surgery.

The lifestyle clinic operates twice a week and it is led by dieticians. Patients attend in total 6 visits, on average one month apart. After the last visit at the lifestyle clinic patients are discharged and advised to continue the dietary regime for life, while also having the option of attending group support sessions.

The pharmacotherapy clinic operates weekly and it is led by a physician. On average 14 patients are seen out of whom, 10 are new referrals and 4 follow-ups. Two types of drugs are administered, reviewed initially after a 3 month period and then after 9 months. Successful patients are discharged to the care of the general practitioner to continue on a lifelong treatment. If one type of drug does not work for the patient, the second type of drug is considered. If none of the drug types works, patients are either referred to the lifestyle clinic, surgical clinic or discharged.

The surgical part of the obesity service involves a range of outpatient appointments and a surgical procedure. Patients are first seen in an outpatient clinic referred to as the Eligibility clinic by the physician and psychiatrist to assess whether surgery is appropriate. At the time the study was undertaken, 10 patients were seen per week on average. Patients, with psychological co-morbidities that need further optimization are sent for a 3-month psychiatric review and if an improvement is achieved, they are then referred for a surgical opinion. In the next clinic called Decision clinic, a surgeon assesses the patient to establish if he/she can safely have an operation. Patients are allocated an operation using a simplified first in first out (FIFO) rule in the model. They are then reviewed in a Pre-assessment clinic led by an anesthetist before their scheduled operation. If the patient passes the necessary health checks he/she is scheduled for one of the three types of surgical interventions (gastric band, sleeve gastrectomy or gastric bypass) in proportions that match actual data in the next available slot in the operating theatre list. At the time (in 2009) three half-day operating lists took place weekly led by one surgeon. The number of operations would vary depending on the type of surgery. Post-op care is next provided to patients before being discharged. Patients are admitted on the day of surgery and post-op care varies from half a day (gastric banding) to two days (sleeve gastrectomy, gastric bypass) depending on the type of surgery.

Some aspects of the real life service which were not relevant to the objectives of the study were not specifically modeled for simplification purposes. Simulation models are simplified representations of the real life. Including too much detail can make the models unnecessarily complex to model and slower to run (Robinson 2004). For example, the resources of interest for this study were the time slots for outpatient clinics or operations, hence staff specialties (i.e. nurses, anesthetists) and infrastructure components (e.g. equipment and operating theatres) were not included in the model. Repeat outpatient appointments after a patient has completed treatment have not been included in the model. In this study patient movement is best represented in days, hence the model uses a time unit of one day. Subsequently, results on patient waiting times are represented in multiples of days, converted in weeks. The data used in the simulation model are real life data provided by the obesity service in collaboration with which this study was undertaken.

The simulation model was validated by the modelers and members of the centre to ensure that it adequately represented the real life service. An effort was made to ensure that the results of the baseline model were relevant to existing real life statistics, such as the number of patients discharged by clinic (e.g. lifestyle, pharmacotherapy), by type of operation (e.g. gastric band, gastric bypass and sleeve gastrectomy) and number of bed days used. Members of the obesity team found simulation results consistent with their experience and data. These tests ensured that the model was valid and so future scenarios could be next developed. It is standard practice in DES modeling to improve the accuracy of model results by dealing with initial transient effects (due to the service starting empty) and by running the model several times in parallel referred to as multiple replications (Law 2007; Robinson 2004). The latter means that the model is run in parallel several times to ensure that different layers of variability are captured in the results. Statistical calculations provided a warm up period of one year to deal with initial transient effects and 30 multiple replications to run each computer model (Hoad, Robinson, and Davies 2010).

A screenshot of the simulation model is provided in Figure 1 to enable the reader to appreciate the graphical nature of DES models.

Figure 1 goes here

Performance indicators

The performance indicators are the results collected from the models relevant to patient waits in different parts of the service. Some key results obtained from the simulation model and reported in this paper are:

- Waiting list for Group Induction session represents the number of 1^{st} time patients on the waiting list for induction.
- Waiting List for Pharmacotherapy Clinic represents the number of patients waiting to be seen in the Pharmacotherapy Clinic.
- Waiting List for Operation represents the total number of surgical patients (who opted for surgical intervention at group induction), waiting for surgery at any point in the surgical pathway. This includes the waiting list for the Eligibility clinic, for Decision clinic, for surgery (patients who are allocated a date) and the weekly operating list.
- Waiting time to operation represents the total time (in weeks) patients spend in the system from first referral to the day they undergo an operation.
- The 18 week targets represent the proportion of patients who wait more than 18 weeks from referral until they receive treatment. The lifestyle clinic has not been included in our findings as it is underutilized and both the computer model and centre data support that finding. Two separate performance indicators were calculated for the service studied referring to two different targets. This is relevant for the obesity pathway as the overall 18 week target used in the UK health service (NHS Choice 2011) is not directly suited as in other clinical areas where patients require shorter timescales to first treatment. The first indicator is a combined target counted from first time referral until a first treatment is provided either in the Eligibility clinic or Pharmacotherapy clinic. The second indicator is counted only for surgical patients, where the clock starts counting from Eligibility clinic until patients undergo an operation. At the time of the study these divisions were of interest to the stakeholders of the obesity centre. However, other centers may view the interpretation of the18 week target differently. A different calculation would require a change in the model coding for such calculations but would not invalidate the model itself.

Scenarios

The experiments carried out involve varying a number of parameters, and forecasting the future performance of the centre. They focus on organizational changes that were considered possible by the obesity team with the aim to meet the demand for treatments. The options considered include the following:

- Increase capacity to meet demand, i.e. employing additional staff and investing in new space.
- Eliminate existing excessive waiting lists by introducing temporary measures, i.e. outsource operating lists.
- Manage demand, i.e. monitor referral practice to achieve a reduction in the rate of patient referrals into the service.

Variations to the initial simulation model were made to define future scenarios. Each scenario provides a future view of the service.

We performed two sets of experiments. Initially six scenarios looking 1 year into the future were performed where certain parameters, surgeons, physicians and patient referrals were varied one at a time (Table 2). Our objective was to gain an understanding of the performance of each scenario experimenting with an increase in capacity by employing up to two additional surgeons and/or one additional physician. The baseline scenario represents the obesity system as it was performing at the time of the study, with the equivalent capacity resulting from utilizing 1 surgeon and 1 physician. The introduction of one additional surgeon therefore means doubling the capacity for services requiring a surgeon (Decision clinic and Operation theatre slots). On the other hand, the introduction of one additional physician means doubling the capacity of Group Induction, Pharmacotherapy clinic and Eligibility clinic, which require the physician's expertise. Scenarios 4 and 5 consider the option of managing demand in the form of reducing patient referrals to half of the existing figures.

Table 2 goes here

Although the above scenarios were of interest to the obesity team, practical considerations such as the timelines to put the changes into practice were also considered in a second set of scenarios. For example, hiring extra resources such as surgeons and physicians takes time and the start dates are not necessarily the same. This second set of scenarios provides an understanding of the performance of the service with a phased implementation of changes, however these are not a setting stone as there are no guarantees that the resources would be in place at the exact date. To our knowledge, a phased implementation of future scenarios has not been considered in other DES health care studies.

These scenarios start in January (year1) broken down into phases, where the results of the next phase build on the results of the preceding phase. Two options (A and B) are considered, which differ by the time resources are introduced (parameters are changed) (Table 3). Scenario A includes in addition the option of outsourcing operations as a temporary measure to deal with long waiting lists.

Scenario A models the phased implementation of resources in a two year period starting from January (year 1) to December (year 2). The first phase starts with the addition of one surgeon (doubling surgical capacity at the decision visit and operations), one physician (doubling capacity at group induction, pharmacotherapy and Eligibility clinics) and the outsourcing of 322 operations[1] in April (year 1). It runs until August (year 1). The second phase starts in September (year 1), and runs with three surgeons and two physicians, and half the referral rates until December (year 2).

Scenario B models the phased implementation of resources in three phases, in a three year period starting from January (year 1) until December (year 3). Phase 1 starts with 2 surgeons and 1 physician, running until August (year 1). The second phase starts in September (year 1) running with three surgeons and two physicians until December (year 2). The third phase introduces a 50% reduction in the number of referrals in January (year 3) and runs with the same resources until the end of December (year 3).

Table 3 goes here

The results from all the scenarios are presented in the next section.

Results

Simulation results consist of the average values collected from the 30 multiple replications and the calculated 95% confidence intervals. These are presented in Table 4.

Simple future scenarios (1 year)

The results of the base line scenario show that a high backlog of patients in the different waiting lists would be experienced, if the same level of resources and referral rates were kept in year 1 (as in previous years). On an annual basis, on average 64% of patients would wait for more than 18 weeks until being seen at the eligibility visit or pharmacotherapy clinic from first referral and 47% of surgical pathway patients would wait for more than 18 weeks to be operated from the Eligibility visit. These figures continue to rise, reaching to 100% in the last month (December year 1). It is obvious that the initial level of resources used back in year 0 (start of study), was not sufficient to cope with the new rate of patient referrals into the service, resulting into continuously rising numbers of patients in the waiting lists.

[1] 322 operations was the closest number to 300 that it was possible to model for the purposes of this scenario.

This confirms the team's realization that the service was running beyond capacity and that changes needed to be considered. Scenarios 1-5 represent such changes.

Comparing simulation results of all six scenarios, scenarios 3 and 5 are the best performing ones in terms of patient waiting times in the service. Hence it is concluded that the additional surgeon has a significant impact on the time surgical patients wait for an operation after the Eligibility clinic, reducing the proportion of patients waiting for longer than 18 weeks to 9% (scenario 1). An additional two surgeons (scenarios 3 and 5) reduces this proportion to 8%.

The introduction of an additional physician, results in significantly reduced waiting lists for group induction, pharmacotherapy and eligibility clinic (scenario 2). However, more patients progress to the surgical part of the system, creating a high backlog of referrals waiting for surgery. This is obvious when comparing scenarios 1 (1 physician) and 2 (physicians), where a higher proportion of patients wait for more than 18 weeks (9% compared to 38%). The best performing scenarios are those with more surgeons than physicians. This demonstrates the dynamic behavior of resources and bottlenecks in the system.

Demand management was also explored as a means of dealing with the high volume of patients in the system. A policy considered was to introduce a system where a number of services would be delegated to General Practitioner centers in order to reduce the rate of patient referrals. Scenarios 4 and 5 operate under a reduced patient referrals mechanism. The reduced referral rate allows the physicians to clear the backlog of patients waiting for group induction. As a result the proportion of patients waiting for more than 18 weeks to be seen at Eligibility clinic is reduced from 63% (scenario 2) to 59% (scenarios 4 and 5), especially in the last month (December year 1) where this indicator is significantly reduced from 59% (scenario 2) to 0%(scenarios 4 and 5) of patients. Scenario 5 is the best performing scenario, which ensures an improved performance consisting of 100% of patients waiting less than 18 weeks to be seen at Eligibility clinic or for an operation, beyond December year 1.

Table 4 goes here

Phased implementation of resources scenarios

Scenario A

The phased introduction of one surgeon and one physician in phase 1, results in reduced waiting lists in patient information by August (year 1). Even though 322 referrals are outsourced between April and May (year 1) the available surgical resources cannot cope with the required operations. Referrals waiting for surgery are high, with the percentage of patients waiting for more than 18 weeks to surgery reaching 62% compared to just 9% in simple Scenario 1. This is mainly due to the introduction of the additional physician displaying a similar behavior to scenarios 1-5.

The addition of an extra surgeon and physician and a reduced referrals mechanism in Phase 2 (September year 1), results in reduced waiting lists for group induction, very close to 0. The proportion of pharmacology and surgical patients waiting for more than 18 weeks from first referral to Eligibility clinic does not appear to change from phase 1 to 2 but it becomes 0 from August (year 2) onwards. This is because the target reported in table 4 for each phase is an average value over both phases. However, the percentage of patients waiting for more than 18 weeks to surgery increases to an average of 86%, with December (year 2) reaching 94% within phase 2. The waiting list for surgery remains high at the end of December (year 2) and patients stay in the system on average 44 weeks from first referral to surgery. If the model were to continue simulating the obesity service for a further year (to December year 3) with the same configuration, the percentage of patients waiting for more than 18 weeks for surgery starts decreasing, to become 0 from May year 3.

Scenario B

Phase 1 is equivalent to scenario 1 in the simple future scenarios. The results similarly show that 9% of patients wait for more than 18 weeks to surgery by August (year 1). Patients wait on average for approximately 36 weeks from first referral to operation, slightly less than scenario 1 as this phase stops 4 months earlier.

The addition of one physician in the beginning of the second phase reduces dramatically the waiting list for group induction to approximately zero patients by the end of December (year 2). However, the results show that double capacity for the Eligibility clinic is not enough to clear the waiting list completely. Patients that were in the system on the WL Group induction have moved along the pathway to the WL Eligibility clinic. Hence, a high percentage of patients (73%) wait for more than 18 weeks to receive first treatment (in pharmacotherapy or eligibility clinic) from the first referral over the two year period. This indicator continues to deteriorate towards the end of the period, reaching 89% in the last month (December year 2), due to a buildup of patients in the WL for the Eligibility clinic. On the other hand, the proportion of patients waiting from Eligibility clinic to receiving an operation is slightly reduced and it reaches 0 from March year 1. The WL for Decision clinic at the end of the model run(s) is also on average zero. This is mainly due to the introduction of an additional surgeon. The slots available in the decision clinic are not fully utilized suggesting that fewer slots could be considered (scheduling 2 instead of 3 clinics) to release the third surgeon to undertake other work such as operating on patients. If this scenario was extended for a further year (Dec year 3) or even 2 years (Dec year 4) the WL for eligibility clinic (surgery) and WL for operations would be further reduced, but not completely eliminated. Patients would still wait on average for more than 43 weeks from first referral to operation.

The reduction of referral rates in Phase 3 ensures that the number of patients on the WL Group induction, Pharmacotherapy clinic and Eligibility clinic (surgery) reach values close to zero at the end of the period (December year 3). The percentage of patients waiting more than 18 weeks to first treatment by the end of phase 3 is slightly higher (76%) compared to 73% in December year 2. This occurs due to the increased numbers of patients in the waiting lists carried over from the end of the previous phase. These figures however, start improving at the beginning of year 3, to become 0 in August (year 3). The percentage of surgical referrals waiting for longer than 18 weeks for surgery is the same as at the end of phase 1 and 2 because it represents the average for the overall 3 year period. However, measured on a monthly basis the percentage becomes 0 from March year 2. Surgical patients wait on average for 44 weeks to receive surgery from first referral.

Conclusions and discussions

DES is a powerful technique capable to represent dynamic changes in an operational system (Law 2007; Robinson 2004), whilst effectively handling variability. The benefits of using DES in healthcare have been highlighted (Jun, Jacobson, and Swisher 1999; Pitt 2008; Young et al. 2004), due to its capacity to describe the patient journey in a visual way, where patients go through a sequence of interlinked activities (treatments); and queues of patients waiting to be treated emerge resulting from the available capacity. Most importantly, it can be used to test the effect of different interventions on healthcare delivery (Young et al. 2004).

We developed DES models of an obesity service to evaluate the performance of patient waiting times and lists under different scenarios. These models were used to guide the decisions made by the centre to add additional capacity in the service in a timely fashion. In the intervention reported here, performance indicators such as patient waiting times at various points in the system and the proportion of patients violating the targets were of interest to the stakeholders involved. The simulation models and results provided insights about the performance of the service in the future, which were not possible to appreciate without simulation.

The study found that the addition of surgical resources brings about improvements in patient waiting times in the surgical part of the service. However, this change coupled with the addition of one physician, deteriorates service performance. This shows that the resource levels of 2 physicians and 2 surgeons are not ideal because the available surgical capacity is not able to accommodate the added number of patients in the surgical waiting lists. Better service levels are achieved with 2 physicians and 3 surgeons. This finding may well be relevant for resource configurations at other treatment centers.

Furthermore, the results show that only by introducing dedicated resources that increase the capacity of obesity services is not possible to improve service levels.

Managing demand for obesity treatments by controlling the number of patients referred into the service was considered important. A substantial reduction of referral rates to the obesity service ensures that the obesity service can meet demand. This finding calls for a more integrated approach to planning for obesity services, involving care providers at primary, secondary and tertiary levels. This fits with suggestions made by other studies on obesity (Gortmaker et al. 2011).

The results and insights gained by this study were found useful by the obesity team, who introduced changes to their service based on the understanding gained about the performance of their service from the simulations. The most important outcomes were the addition of more surgeons instead of physicians and the engagement between the AHSC and the Primary Care Trust to change the local eligibility criteria for bariatric surgery and thus reduce the number of referrals to the centre. The DES models at a conceptual level can be used by other clinical services that are keen to supply treatment services that meet the equivalent patient demand.

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Acknowledgments

This study was funded by the UK Engineering and Physical Sciences Research Council (EPRSC) grant EP/E045871/1.

Table 1: Input parameters to simulation model in baseline scenario

Parameter	Resources	Value in baseline scenario	Distribution type
Referral rate		100 patients/month	Poisson
Group Induction (one group session per week)	Nurse Physician Surgeon	up to 20 patients/week	
Following Group Induction			
Patient assessment		93%	Bernoulli
Do not continue		7%	Bernoulli
Patient assessment (once a week)	Nurse	up to 20 patients/week	
Following patient assessment			
Lifestyle clinic		5%	Bernoulli
Pharmacotherapy clinic		16%	Bernoulli
Eligibility for surgery clinic		79%	Bernoulli
Lifestyle clinic (two group sessions per week)	Dietician	up to 8 patients/week	
6 separate appointments/patient			
Time period between appointments		20 working days (1 month)	Triangular
Pharmacotherapy clinic (once a week)	Physician	up to 14 patients/ week	
Following pharmacotherapy			
Receive drugs (drug A)		84% success rate	Bernoulli
Receive drug B (if drug A fails)		80% success rate	Bernoulli
If drugs A and B fail,			
Referral to surgery		15%	Bernoulli
Referral to lifestyle clinic		10%	Bernoulli
Discharged		75%	Bernoulli
Eligibility clinic (outpatients)	Physician Psychiatrist	up to 10 patients/week	
Following Eligibility clinic			
Decision clinic (surgery)		60%	
Psychiatric review		30%	
DNA surgery		10%	
Decision (for surgery) clinic	Surgeon Dietician	8 patients/week	
Pre-assessment clinic (2 weeks before the scheduled operation)	Anaesthetist Nurse	8 patients/week	
Operations (3 types of surgical procedures)	Surgeon Anaesthetist	3 half day theatre lists/week	
Gastric band (1hr procedure)		19%	Bernoulli
Sleeve gastrectomy (1.5hr procedure)		22%	Bernoulli
Gastric bypass (2hr procedure)		59%	Bernoulli
Post-operative length of stay following	Beds	Depending on type of surgery	
Gastric band		1 day	
Sleeve gastrectomy		2 days	
Gastric bypass		2 days	

Table 2: Parameters defining the six simple future scenarios

Scenario	Resources	Monthly patient referrals	Group Induction	Pharma-cotherapy clinic	Eligibility clinic (surgery)	Decision clinic (surgery)	Operations per week
Baseline	1 surgeon, 1 physician	100	20	14	10	8	6
1	2 surgeons, 1 physician	100	20	14	10	16	12
2	2 surgeons 2 physicians	100	40	28	10	16	12
3	3 surgeons, 2 physicians	100	40	28	20	24	18
4	2 surgeons, 2 physicians	55	40	28	20	16	12
5	3 surgeons, 2 physicians	55	40	28	30	24	18

Table 3: Parameters defining the Scenarios for staggered implementation

Scenario A: Outsourcing operations, hire of 2 surgeons and 1 physician, reduced referrals	**Surgeons**	**Physicians**	**Patient referrals**	**Simulated Time**
Phase 1: Jan year 1-Aug year 1	2 surgeons, outsourcing 300 operations (April year 1)	1, 2nd physician (April year 1)	100/month	33 weeks
Phase 2: Sept year 1-Dec year 2 (continues after Phase 1)	3rd surgeon (Sept year 1)	Same as above	55/month (Sept year 1)	71 weeks
				104 weeks (2 years)
Scenario B: Hire of 2 surgeons and 1 physician, reduced referrals				
Phase 1: Jan year 1-Aug year 1	2 surgeons	1	100/month	33 weeks
Phase 2: Sept year 1-Dec year 2 (continues after Phase 1)	3rd surgeon (Sept year 1)	2nd physician (Sept year 1)	100/month	71 weeks
Phase 3: Jan year 3-Dec year 3 (continues after Phases 1 and 2)	Same as above	Same as above	55/month (Jan year 3)	52 weeks
				156 weeks (3 years)

Table 4: The effect of different resourcing scenarios on patient waits, mean estimated values and 95% confidence interval (rounded to the nearest integer)

Scenario	WL Group Induction		WL Pharmacotherapy clinic		WL for Operation		Waiting time to operation (surgery patients only)		Wait > 18 weeks* (target for Pharmacotherapy and Eligibility combined)		Wait > 18 weeks† (Target for surgery patients only)	
	Mean # patients	95% CI	Mean # patients	95% CI	Mean # patients	95% CI	Mean # weeks	95% CI	%	95% CI	%	95% CI
Baseline	523	507-540	141	130-153	791	781- 800	39.6	39.2-39.9	64%	63-65	47%	46- 47
1	526	510-541	140	128-151	541	530- 552	39.7	39.3-40.2	64%	63-65	9%	6-12
2	4	1-7	0	-	833	816-851	39.5	39.0-40.0	63%	62-65	38%	35-41
3	14	10-19	0	-	576	558- 595	35.8	35.2-36.4	74%	61-87	8%	7-10
4	1	0-2	0	-	596	587- 605	39.5	39.0-40.0	59 %	58-60	38%	35-40
5	16	12- 21	0	-	191	178- 205	34.7	34.0-35.4	59%	58-60	8%	7-10
Scenario A												
Phase 1: Jan year 1-Aug year 1	53	41-66	39	32-46	465	453-477	*39*	38.5-39.2	59%	57-60	62%	61-63
Phase 2: Sept year 1-Dec year 2 (continues after Phase 1)	2	0.6-2.2	0	-	256	239-272	*44*	43-45	59%	57-60	86%	85-86
Scenario B												
Phase 1: Jan year 1-Aug year 1	450	434-435	145	134-157	497	488-507	36	35-36	57%	56-58	9%	6-12
Phase 2: Sept year 1-Dec year 2 (continues after Phase 1)	5	3-7	1	0-2	727	706-750	44	43-45	73%	72-74	7.6%	4-10
Phase 3: Jan year 3-Dec year 3 (continues after Phases 1 and 2)	2	0-3	0	-	264	243-284	44	44-45	77%	76-77	7.6%	4-10

* from initial referral to Eligibility or Pharmacotherapy clinic; † from Eligibility clinic to Operation.

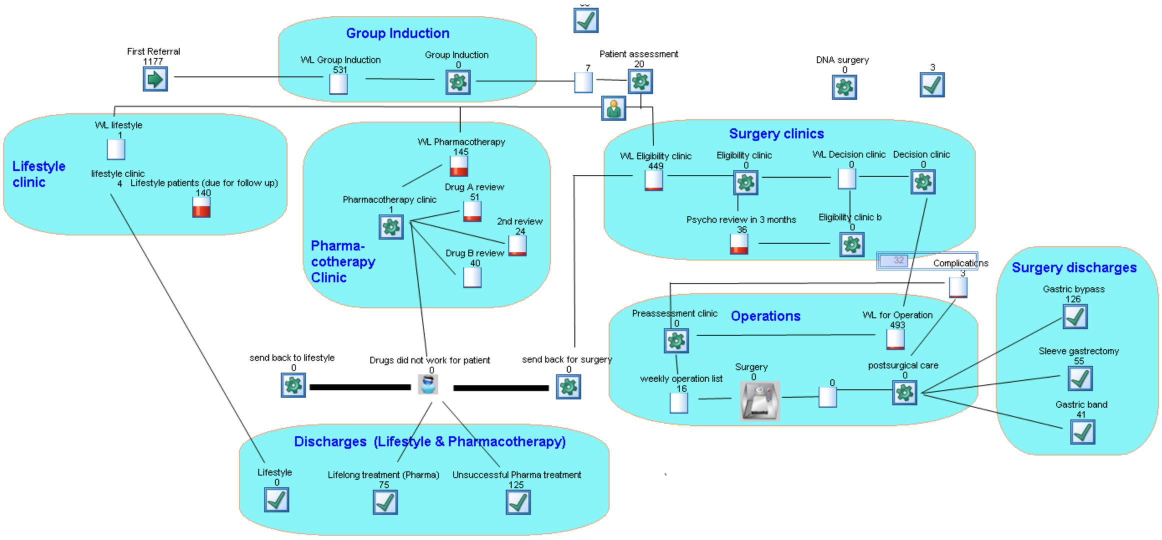

Figure 1: Screenshot of the simulation model of the obesity service