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Application of Lean Thinking Using Simulation Modeling in A Private Hospital

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***Abstract*—Timely access, prompt responses to patient needs, and availability of resources to deliver quality service are the key priorities of healthcare systems, in particular hospitals. To cope with these constraints, healthcare managers have turned into lean thinking and approaches in their attempts to reduce non-value added activities and save costs by reducing wastes. This paper presents a case study of a private hospital in Dublin that used integrated approach of value stream mapping and simulation modeling to assess lean implementation in admission and discharge processes. Simulation enabled the strategic management to examine the outcomes of three possible improvement scenarios on hospital performance before implementing lean strategies. The proposed methodology helped to identify bottlenecks and non-value added procedures. Results analysis showed potential improvement in patients' admission and discharge cycle times, and offered the hospital the cost saving opportunity of reducing the numbers of bed required.**

Keywords-Lean; Modeling and Simulation; Healthcare.

I. INTRODUCTION

Healthcare resources, like those in any other industry, are in high demand, and the current economic climate challenges both public and private hospitals to contain costs whilst optimizing their use. [1] outlines the challenges that face healthcare: slow economic recovery, rising costs and reduced rates of reimbursement by insurance companies, to name a few. Whilst their focus is on the US healthcare economy (which is primarily private) the issues faced are applicable worldwide. In Ireland, the last twenty years or so (pre recession) has seen an increase in people's earning and subsequent purchasing power, with a consequent rise in the percentage of the population with private health insurance, to around 46 per cent of the population [2], which equates to 2.25 million private healthcare policy holders. However, this has led to a dichotomy: far from reducing the pressure on public services, the upsurge in private health insurance and the aging population profile have brought new demands for services in both public and private sectors. So, the number of private providers responding to this need has also increased over the last decade or so. Whilst healthcare is seen as relatively recession proof, the prolonged economic recession has impacted on all healthcare providers, increasing expectations on health service providers to raise service efficiency from external entities such as the government, the public/patients and, of course, insurers. Whilst such efficiencies have always been the focus of the private sector, in recent years the requirement has been expressed with renewed vigor. When dealing with challenges such as reducing costs, a hospital must take a strategic medium- to long-term view on how to proceed to how best to serve all its stakeholders fairly. Such strategic decisions determine how the organization will align itself with its environment [3].

To ensure the best possibility of survival, organizations must scan the horizon for opportunities and capitalize on those that exploit their core competences. In the private sector, companies it must scan the horizon for opportunities, and capitalize on those that best exploit their core competences to give them the greatest chance of survival. These opportunities may include using frameworks and tools from other industries - and such tools can be adapted and developed to help healthcare organizations address their challenges. Lean thinking and simulation modeling offer two distinct frameworks which organizations can use to streamline their processes.

In the rest of the paper, Section 2 reviews related work. Section 3 introduces project background. The proposed methodology is presented in Section 4, followed by experimentation and analysis in Section 5. Section 6 presents limitations and future work, while Section 7 concludes the paper.

II. LITERATURE REVIEW

Lean healthcare is the philosophy of improving flows of patients, information or goods by eliminating waste from the process [4] through 'understanding current processes, identifying the areas for improvement, and implementing necessary change' [5]. The Lean approach seeks improvements within the organization's existing processes but without the substantial reorganization that would require costly investments. Waste erodes quality and results in 'inefficiencies, higher operating costs, increased potential for errors and worker frustration' [6] – so, the logic behind lean thinking is to pursue the optimization of value streams (from the consumption point of view) by eliminating waste and non-value added activities. To identify the sources of such waste and non-value added activities, as well as opportunities of improvement, value added activities must be mapped using systematic tools and techniques [7]. A value stream can be defined as the collection of activities that are operated to deliver a product or service or a combination of both to a customer [8]. The Value Stream Map (VSM) technique demonstrates material and information flow, maps out value-added and non-value-added activities and provides time-based information about performance. This VSM technique is based on generating a current state map that shows the current performance and conditions of the studied systems, and a future state map which serves as a target for

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improvement actions. Its simplicity and effectiveness have led to VSM being effectively integrated into several applications, appropriate to both manufacturing and non-manufacturing situations. Although the lean concept originated in the automobile industry, the increased application of lean practices in healthcare has seen growth in the popularity of modeling tools such as VSM [9]. VSM has been successfully utilized as a lean implementation tool in many different healthcare systems, from small physician's clinics [10] to larger and more complex systems such as Emergency Departments.

Although VSM is very effective in presenting system parameters such as operation cycle times and resource capacities and availabilities, it does not have the ability to analyze the impact of system settings on performance. Various authors agree that the potential for lean healthcare exists, but evaluating its successful implementation remains a challenge [11]. Others argue that lean healthcare has too often been adopted unquestioningly and may actually result in more harm than good: [12] argue that the redesign of healthcare's complex processes 'leads to continued fragmentation of healthcare work, loss of autonomy for the health professions, and a potential increase in hospital misadventure'. This is due to the fact that VSM lacks prediction capabilities, so, it is also difficult to know if the desired level of system performance is the best that can be achieved. Moreover, value stream maps cannot take account of system variations and uncertainty [13], so, VSM must be integrated with another technique that can handle system variation, show dynamics between system components and validate the future state before any improvement steps can actually be implemented. Modeling and simulation can fulfill this need. Modeling and Simulation tools have the capabilities to fulfill this need.

Simulation can be used to master new business concepts such as agile and lean management [14]. Unlike VSM, simulation offers more thorough analysis of a system's data, including examining its variability, determining whether the data is homogenous, and estimating the probability distribution that fits the patterns of the data. This kind of in-depth analysis of data enables simulation to be used to support continuous improvement [15] and to model systems' future state maps, so, showing the ideal state of the system that can be pursued over time. The advantage of using the simulation approach in a lean context is not limited to the phase of developing a future state map, but extends to selecting the best alternative to the current system status.

III. Project Background

The tertiary partner hospital in this study is a private hospital in Dublin which provides a full range of services, including (among others) an Orthopedic centre, Oncology/radiotherapy care, eight operating theatres, and an Emergency Department (ED) that operates 12 hours a day, six days a week. There are two particular drivers for this project:

- Patient perceptions of Quality. Quality can have many definitions - a product's quality can refer to whether it works or not, looks good or not, adds value or not. In the case of service, quality is much more subtle - it depends on both the provider and the recipient - here, the patient– it is all about their perception of the experience. Delays in any process result in patients literally sitting or lying around. For a fully conscious patient this can be frustrating, as there is no perceived value in waiting, unless it is recovering after illness or surgery. However, many patients also attend the hospital as in-patients for diagnosis, so, there are plenty of opportunities and potential causes for delays.

- The continuous improvement ethos of the hospital. The hospital has been through the Joint Commission International Accreditation (JCI) process twice, which requires that all aspects of managing the hospital - from leadership to infection control to the patient journey - are clearly stated for all staff to see. This is to be achieved through written policies, procedures and guidelines, and the whole process of setting everything down in writing is a good way of spotting gaps in the service offered. The JCI process sees continuous quality improvement as a cornerstone to accreditation, and requires quality improvement be embedded in the organization's culture. The hospital has Key Performance Indicators (KPIs) and performance benchmarks. It constantly strives to improve its processes, and runs quality improvement initiatives, both large and small, both within departments and hospital wide.

The hospital's Quality Improvement Committee meets monthly to discuss policies, procedures and quality initiatives in the hospital. Amongst the quarterly statistics and KPIs it considers is the average Length of Stay (LOS) of patients. LOS figures are averaged over the whole hospital population, although in reality lengths vary according to patient diagnosis, and many factors contribute to LOS variations, both qualitative (individual doctor practice style, individual patient diagnosis) and quantitative (discharge policy implementation, bed supply, method of payment) [16]. Delays in patient discharge are due to various factors: inconsistent discharge rounds (doctors attending when they can), delays in waiting for tests and in discharge prescriptions and late referrals to allied health professionals. The delayed discharges have a negative impact on availability of acute beds, admissions of elective and emergency admissions and overall patient experience. Currently the discharge process in the partner hospital depends on when consultants conduct their ward rounds. If it is decided to discharge a patient it is recorded in the patient's chart. A junior doctor then organizes any medications and last minute tests, and the patient's discharge summary, and the nurse notes when the patient leaves in their electronic record on the Hospital Information System (HIS). Discharge data on the HIS shows discharges primarily occur after midday, which has a negative impact on the availability of beds for both elective and ED admissions. The admissions process for both elective and ED patients can be quite lengthy. The main problem is the assignment of a bed for the incoming patient, which can be affected in leaving patients are discharged late, which may not only lead to patients experiencing significant delays, but to them being assigned to an inappropriate ward if there is no bed available on the appropriate ward. This means consultants have to make rounds to other wards as well as those they are primarily assigned to, and necessitates further ward transfers when an appropriate bed does become available. If the bed manager had better information regarding bed availability s/he would be able to make more efficient admission decisions. At the beginning of this study, there was too much waste in the system but where exactly it arises needs to be clarified. Operations meetings have also highlighted the need for the hospital to have strategies for coping with unexpected influxes of admissions, when bed availability becomes critical. This paper describes a collaborative project between the bed management team and the research team. The main objective is to analyze the situations which cause discharge delays and propose valid solutions.

IV. PROPOSED METHODOLOGY

As identified earlier, lean thinking helps remove or limit the impact of non-value adding steps in a process. However, lean management requires a team of people; it is an expensive method of process redesign. Implementing an unsuitable or ineffective change creates further waste, as well as frustration. Simulation modeling offers the opportunity to test process alternatives in a safe environment. The issue outlined (i.e., the admission-discharge process) is a day-to-day problem which has implications for strategic planning. As the work involves processes at the patient level Discrete-Event Simulation (DES) is suitable. The objective is to aid the bed administrator to allocate beds more efficiently, which will impact positively on the LOS of both the elective and ED admissions (both of which currently suffer delays due to the ad hoc discharge process) increasing patient satisfaction. An important added benefit is that this will help the hospital prepare better for any 'bed crises'. Using lean principles as the foundations, the framework devised for examining these issues involves 1) identification of the process; 2) identification of the value to the patients; 3) develop VSM for the process(es); 4) develop the simulation model; and 5) experimentation and analysis.

A. Identification of the Process

There are many distinct processes in a hospital, but they are all inter-connected. Fig. 1 presents the overall patient journey, whether they enter the process as an elective candidate or via the Emergency Department, where they will have been diagnosed as requiring further treatment as an in-patient. The Bed Manager then allocates the patient a bed, and they are given in-patient treatment until they are discharged home, or for further treatment elsewhere, or (in the worst case) to the mortuary.

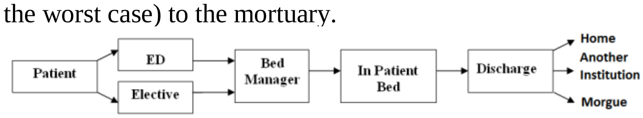

Figure 1. Overall admission-discharge process

B. Identifying the Value to the Patient

Literature shows a link between discharge and admission rates: both the elective and ED admission processes were reviewed separately with respect to the affect delayed discharge had on bed allocation. The time the patient spends in the admission process can be viewed as part of their overall LOS. Delays in either admission or discharge are non-value added 'activities' which directly affect the patient's perception of the quality of their diagnosis/treatment; delays for the patient are frustrating at best and life-threatening at worst. Other 'customers' who are indirectly affected by delays in the process include referring doctors (who want their patients to be treated effectively and efficiently) and insurance providers.

C. Develop Value Stream Maps for the process(es)

Value stream mapping (VSM) gives a pictorial representation of the flow of materials, people and process information from the start to the end of a process. It includes all activities involved in the process, whether they can be categorized as value-added (e.g., blood tests); non-value added necessary (e.g., the patient completing their insurance details); and non-value added unnecessary. This can highlight problems and can help identify their causes, assisting managers in prioritizing process improvements. The overall pictorial representation VSM gives can also enable other stakeholders (doctors, senior management and accreditation inspectors) to appreciate the process more easily and more fully. One the process to be mapped has been selected, VSM involves 1) talking to frontline staff involved in the process (here, bed manager, ED manager, admission clerks, etc.) to map each stage of the process on paper 2) collecting data to produce a current state map; and 3) conducting a critique of the current state to identify wasteful areas of the process which offer the best chance of being changed.

1) Elective Admission VSM

Fig. 2 shows the VSM of the admission of elective patients, with relevant information attached to each step of the process: 1) capacity (i.e., number of people available to perform that step); 2) type (i.e., personnel required to perform that activity); and 3) P/T: process time is the time required to complete the activity. The averaged time taken at each step of the process is recorded in a time line at the bottom of each image - for example, the time taken for the Bed Manager to assign a bed for an elective admission can take between 10 and 15 minutes, so, is averaged to 12 minutes. The timeline is presented from the patient's perspective, and includes process time and wait time. Process time represents value added activities, usually involving the patient (e.g., transfer to the patient room, attending radiology for a scan) while wait time is the time spent in an activity the patient is not involved (e.g., waiting for a bed to be assigned).

2) ED Admission VSM

The developed VSM constitutes of two parts – the main process (Fig. 3) and a sub-process (Fig. 4), which shows the patient having a scan in radiology. The associated time lines are shown at the bottom of each figure where these figures are the most likely value for the corresponding step (i.e. triangular distribution). The map was created to illustrate the impact delays in the diagnostic process can have on an ED patient's admission experience. Mapping the sub-process

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adds complexity to the model, making it a truer representation of the real system and increasing the quality of the simulation model.

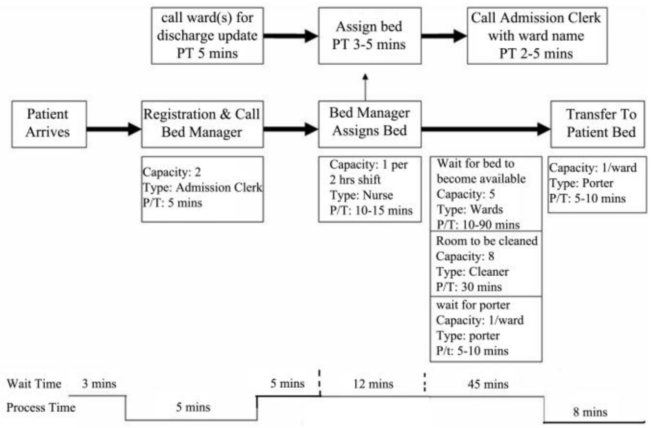

Figure 2. VSM Elective admission process

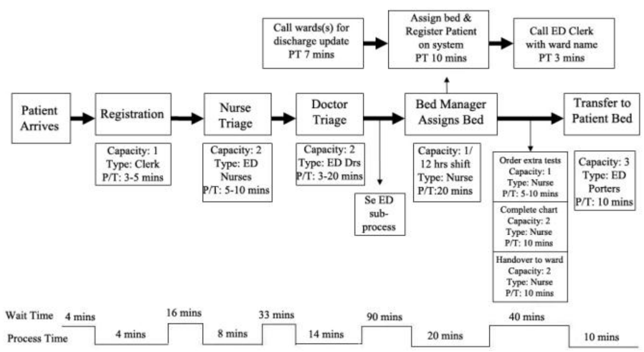

Figure 3. VSM ED admission process

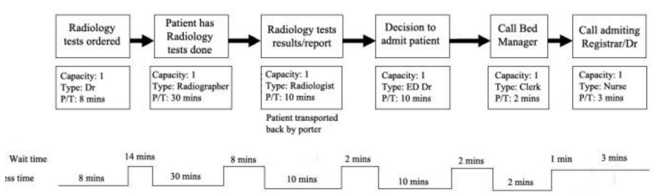

Figure 4. VSM ED admission sub- process

The times assigned to each step in the ED admission process was collected through observations carried by medical and administration teams. These times were summed according to type to determine where the overall process suffers most in terms of non-value added activities: the ED sub-process was evaluated separately as it contains both waiting and processing times. Table I shows the results.

TABLE I. VSM WAIT, PROCESS AND TOTAL TIMES

Time (mins)	Wait		Process	Total
Process	Non value add - necessary	Non value add - unnecessary		
Elective admission	3	62	13	78
ED admission	0	93	56	
ED sub-process	20	10	60	
	20	103	116	239

The total time taken for the elective admission is 78 minutes, which may seem surprising given that these patients are scheduled appointments. The total time taken for ED admissions (including the sub-process) is 239 minutes, nearly half of which this is non-value added elements composed of the waiting involved between steps. The two longest wait periods occurs when 1) diagnostic tests are required – these may involve long scan times (MRI) or preparation (patients drinking contrast medium before a CT scan). These activities can be seen as non-value-added but necessary in order to have the scan; and 2) Awaiting for a bed to be assigned and to become available, which are non-value added elements.

D. Developing the Simulation Model

The analysis of empirical data is essential in developing a robust simulation model that considers the time features of the examined system in terms of the volume and patterns of demands. Historical records were gathered from the hospital information system over a 6 months period, as provided by hospital managers. The data included occupancy rates, elective, ED and overall admission numbers. The average percentage of late discharges (after noon) was determined as 83 per cent (see Fig. 5).

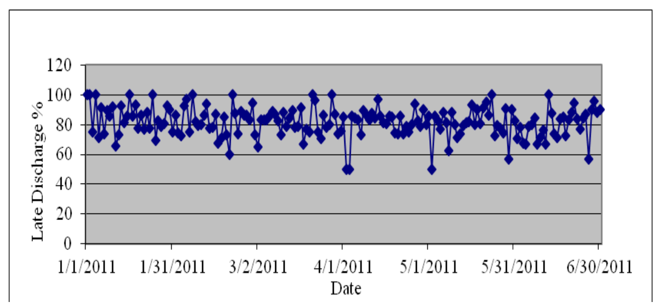

Figure 5. Late discharges as percentage of overall discharges

As the discharge process affects bed availability, average bed occupancy levels was determined to be 91% due to the high rate of late discharge (Fig. 6). Average bed occupancy levels were determined to be 91% (Fig. 6). We argue that the discharge process - and specifically, late discharges - is a significant factor in this figure, which we argue is too low. The simulation model was designed to reflect this relation between the late discharging rate and the bed management performance issues. The data collected was also analyzed to extract the arrival rates of patients after categorizing them to ED patients and out patients after they had been categorized into those needing admission, and those need out-patient care (Fig. 7).

Based on this analysis of empirical data and the VSM results, a comprehensive simulation model was developed for the admission-discharge cycle(s) in the hospital. Simulation model modules were connected to resemble the VSM processes, where blocks are connected to create conceptual flow chart, which simplifies the construction of the simulation model.

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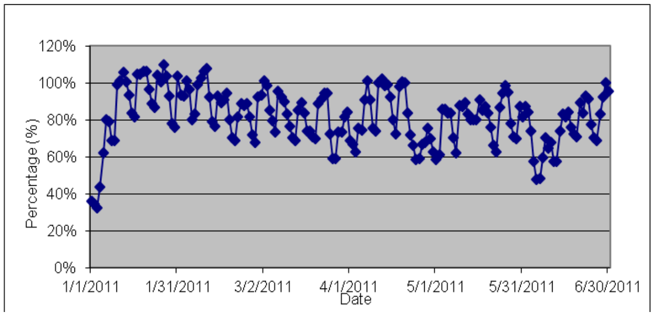

Figure 6. Bed occupancy levels over a 6-month period

Thus, the top level of the simulation model defines the overall model structure, with the sub-level blocks containing additional modules with more details. The simulation model was developed using ExtendSim package and object-oriented programming was used to customize pre-defined blocks. A database was used to save the measured KPIs (i.e., avg. occupancy levels, avg. LOS, and avg. waiting time for ED admission) after each simulation run, after which the simulation output was exported in tabular form for future analysis and validation.

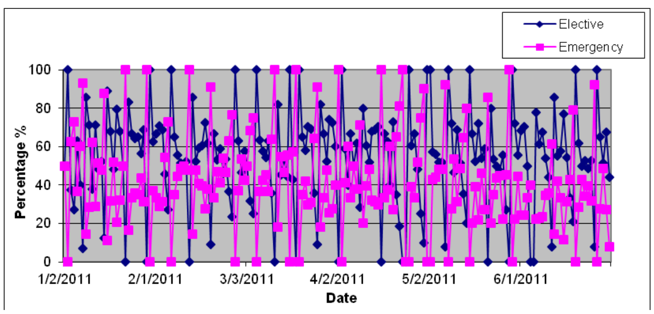

Figure 7. Number of admissions for ED and elective patients

E. *Verification and Validation*

Developing the simulation model depends on the right process being modeled and it being modeled (or built) correctly. As disconnects can exist between real world problems and models of those problems, the verification and validation processes are crucial. The model used six months data gathered from the HIS to predict average occupancy within four per cent of actual values. Literature states 10 per cent statistical accuracy as being an acceptable level (Connelly and Bair, 2004). Fig. 8 shows the correlation between predicted and actual occupancy rates.

Real (blue line) refers to the original data set, but these included bed in the observation ward, which opened on day 136. Their inclusion increased the number of total beds available, thus, skewing the data, so, it was decided to remove the observation beds from the analysis. This ‘new’ data is represented by the ‘Real after modification’ (green line). The ‘Simulated’ (red) line represents the values predicted by the model - as the figure shows, these two track each other.

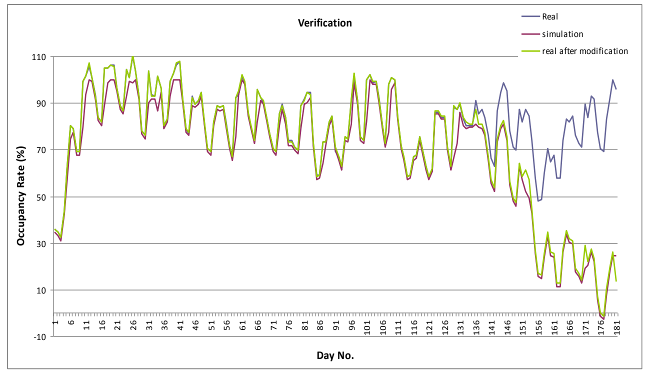

Figure 8. Correlation between predicted and actual values

V. Experimentation and Analysis

A. *Scenario Design and analysis*

Bed availability becomes a significant problem if there is an increased demand due to ED admission rates or the effect of late discharges. Increasing the number of beds in the hospital and improving the discharge planning for patients were the main two solution options the management team wanted the model to examine and analyse. Two variables were introduced to examine these strategies: number of beds available and late discharge rate, and three main scenarios were then introduced, as shown in Table II.

TABLE II. Simulation Variables for Base Scenario and Scenarios 1, 2, and 3

	Number of beds	Late discharge rate
Baseline Scenario	145	83%
Scenario 1	110 to 170 with a step of 5	83%
Scenario 2	145	0 to 1 with a step of 0.1
Scenario 3	110 to 140 with a step of 5	0 to 1 with a step of 0.1

It could be expected that increasing the number of beds above the current level (i.e., 145 beds) would lower bed occupancy levels and decrease ED waiting times, while decreasing available bed numbers (without changing any other variables) would lead to significantly increased delays for patients waiting to be admitted (Table III). However, changing available bed numbers caused no significant change in penitents’ average LOS in the hospital, because the discharge process still unchanged (i.e., the late discharge rate remained constant at 83%).

On the other hand the simulation shows that reducing the late discharge rate (i.e., scenario 2) would have a significant impact on the average LOS (see Table IV).

As the Table IV shows, continuously decreasing the proportion of late discharges constantly decreases bed occupancy levels, allowing the hospital the opportunity to decrease its number of available beds instead, with the attendant cost savings. To examine this possibility in more detail, the model examined (as scenario 3) a combination of different discharge rates and the potential associated reductions in bed numbers.

TABLE III. SIMULATION RESULTS OF SCENARIO 1

Number of Beds	Bed Occupancy	ED Waiting Beds (hrs)	Avg LOS (days)
110	95	13.8	4.5
115	95	12.1	4.5
120	94	9.6	4.5
125	93	3.2	3.9
130	93	5.1	4.3
135	92	3.5	4.4
140	92	3.3	4.4
145	**91**	**2.4**	**4.4**
150	83	0.7	4.2
155	81	0.4	4.3
160	78	0.2	4.3
165	74	0.1	4.3
170	71	0.1	4.3

TABLE IV. SIMULATION RESULTS OF SCENARIO 2

Late Discharge Rate	Bed Occupancy	ED Waiting Beds (hrs)	Avg LOS (days)
0	51	0.0	2.1
10	56	0.0	2.4
20	61	0.0	2.7
30	64	0.0	2.8
40	70	0.0	3.2
50	73	0.0	3.4
60	79	0.2	3.7
70	85	0.9	4.1
80	**91**	**2.4**	**4.4**
90	93	6.7	5.0
100	98	13.7	5.8

Interestingly, as the rate of late discharges decreases, the possibility of reducing the number of beds increases, while the quality of care for patients in terms of waiting times for beds and LOS in hospital also improves (see Fig. 9). These results of the simulation scenarios suggest that increasing bed numbers can be considered a knee-jerk reaction and will only solve the problem temporarily; as once more beds become available the referral rate for elective procedures will also increase. From an operations perspective, new beds are very expensive because they have to be staffed appropriately and there may often be limited physical space available to respond to higher occupancy: so, this is not a realistic option.

It is clearly more efficient and cost-effective to review the discharge process to identify effective actions to decrease delayed discharges. This goal can be accomplished by early medical assessments (ward rounds), faster laboratory or diagnostic imaging results; fulfilling prescriptions in the pharmacy in a timely manner; and discharging patients to alternative care settings. The majority of patients' discharges are delayed because a nursing home bed, homecare packages, other community supports, rehabilitation facilities or other types of alternative care are not available. In an analysis of the reasons for the delay in discharging it was found that 75% of those patients were seeking nursing home care. Therefore providing short- and long-term beds has a substantial effect in reducing waiting times in many other stages of healthcare system. As acute hospitals become more technologically advanced in diagnostic and interventionist care, perhaps they are no longer appropriate settings for convalescing. Hospitals may want to consider 'step down units' as an option for the future, which would dove-tail well with the increasing current use 'hub and spoke' model. Hubs are based in large conurbations not served by tertiary care hospitals, and specialist clinics in these towns refer patients to the underlined studied Hospital for specific sub-specialty care such as orthopedic surgery, vascular surgery.

VI. LIMITATIONS AND FUTURE WORK

While the information gathered for the VSM came directly from people involved, the quality of the data was not actually audited, so, assumptions and estimates had to be used for some steps. The documentation methods used to record some steps of the processes – hand-written notes in the patient's physical chart and entries on the patient's electronic record - can make capturing data about those steps difficult. And while simulation modeling can present possible solutions and the impact changes can have on a process, it does not take account of all the varied and often challenging professional bureaucracy environments.

VII. CONCLUSION

Further investigation is also required to substantiate preliminary findings, as certain assumptions were made, primarily about the discharge process (as noted previously). So, future work should incorporate a small team of people directly involved in the processes to gain results data of richer quality. Use DES modeling in conjunction with system dynamics model to work with, rather than against, each other. Hospital processes are interdependent and their efficiencies (or wastes) affect others, so, a system-wide (aggregate) view should be modeled. The person most affected by the whole system is the patient. The DES can inform the SD model to identify potential synergies between processes. This work discusses the practicalities, challenges and limitations of applying lean healthcare modeling to a hospital process – so, it represents a risk assessment for process change. It incorporates the principles of lean management (focusing on the patient journey through a process and seeking to identify, and so reduce, unnecessary waiting and non-value-added activities) and simulation modeling (testing solutions to balance capacity and demand) to improve the delivery of healthcare to patients. The problem in question is the impact late discharge has on bed availability and admission processes.

Lean principles were applied to the problem, and the processes involved were mapped to achieve greater understanding and so inform the simulation model. Scenarios were run, focusing on the late discharge rate and its effect on numbers of bed required and patients' wait times overall LOS, allowing a future state map to be built. Simulation does not consider the environment or culture around a process - resistance to change may have to be addressed and countermeasures proposed - while a hospital may have a

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change culture, this does not mean the consultants are parties to it.

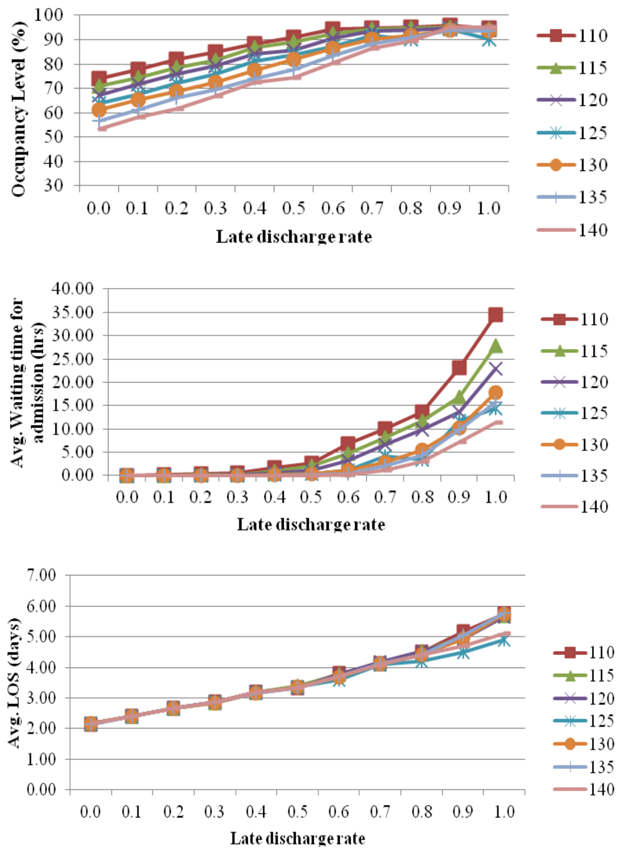

Figure 9. Simulation results of scenario 3

To achieve change, manager may have to seek opportunities for greater collaboration with consultants and include them in hospital change strategies.

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