Post-surgery length of stay using multi-criteria decision-making tool

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Abstract

Purpose – Length of stay (LOS) in hospital after surgery varies for each patient depending on surgeon's decision that considers criticality of the surgery, patient's conditions before and after surgery, expected time to recovery and experience of the surgeon involved. Decision on patients' LOS at hospital post-surgery affects overall healthcare performance as it affects both cost and quality of care. The main purpose of this research is to develop a model for deriving the most appropriate length of stay after surgical interventions.

Design/methodology/approach – The study adopts an action research involving multiple stakeholders (Surgeon, patients / patients' relatives, hospital management and other medics). Firstly, a conceptual model is developed using literature and experts' opinion. Secondly, the model is applied in three surgical interventions in a public hospital in Malta to demonstrate the effectiveness of the model. Thirdly, the policy alternatives developed are compared to a selection of current international standards for each surgical intervention. The proposed model analyses three LOS threshold policies for three procedures using efficiency and responsiveness criteria. The entire analysis is carried out using 325 randomly selected patient files along with structured interactions with more than 50 stakeholders (Surgeon, patients / patients' relatives, hospital management and other medics). A multiple criteria decision-making method is deployed for model building and data analysis. The method involves combining the Analytic Hierarchy Process (AHP) for verbal subjective judgements on prioritizing the four predictors of surgical LOS – medical, financial, social and risk, with pairwise comparisons of the sub-criteria under each criterion in line with the concerned interventions – the objective data of which are obtained from the patients' files.

Findings –The proposed model, was successfully applied to decide on the best policy alternative for LOS for the three interventions. The best policy alternatives compared well to current international benchmarks.

Research limitations/implications – The proposed method needs to be tested for other interventions across various healthcare settings.

Practical implications – Multi-criteria decision-making tools enable resource optimization and overall improvement of patient care through the application of a scientific management technique that involves all relevant stakeholders, while utilizing both subjective judgements as well as objective data.

Originality/value – Traditionally, the duration of post-surgery LOS is mainly based on the surgeons' clinical but also arbitrary decisions, with as a result, having insufficiently explicable variations in LOS amongst peers for similar interventions. According to the authors' knowledge this is the first attempt to derive post-surgery LOS using the AHP a multiple criteria decision-making method.

Keywords – Analytic Hierarchy Process, Hospital, Length of stay, Multi-criteria decision-making, Multiple stakeholders

INTRODUCTION

Hospitals represent the highest proportion of health care expenditure (Organization for Economic Cooperation and Development (OECD) Staff 2013), which is expected to rise with increasing ageing populations (Bloom et al. 2011, Pammolli, Riccaboni & Magazzini 2012). Over the past decade, the European Commission (EC) has acknowledged the need to monitor health systems' performance. Indeed, EC's country-specific recommendations (CSRs) on health systems within the European Semester, focus on curtailing public spending through reduction in hospital beds and in-patient days, as well shifting from inpatient to daycare and primary care (Azzopardi-Muscat et al. 2015). Inappropriate admissions and prolonged LOS are among the leading sources of hospitals' inefficiences (Etienne, Asamoa-Baah & Evans 2010). Optimal decisions in this area can reap substantial cost benefits by enhancing patients' satisfaction and reducing cost. Hospital LOS is expected to vary between countries, hospitals, and across settings, due to variability in procedures and practices. What remains consistent worldwide, is the target of reducing LOS (Organization for Economic Cooperation and Development (OECD) Staff 2013, Clarke, Rosen 2001), though this is not a straightforward undertaking. While a shorter stay will decrease the cost per discharge (Organization for Economic Cooperation and Development (OECD) Staff 2013)(Organization for Economic Cooperation and Development (OECD) Staff 2013), a short LOS may be associated with adverse health outcomes and higher readmission rates, thereby increasing costs per illness episode (Husted, Holm & Jacobsen 2008). On the other hand, a prolonged LOS not only increases costs, but is also associated with adverse events and complications (Senthilkumar, Ramakrishnan 2012, Lim et al. 2006). Therefore, the right balance must be found between ensuring healthcare quality and cost-saving. Improvements in LOS could release capacity by way of beds and staff time (NHS 2008). However understanding the complexity of factors underlying LOS is crucial before one pushes forward realistic targets.

Surgical procedures present major challenges to hospital management and financing (Losina et al. 2012). This study investigates the best LOS policy alternatives after three procedures - laparoscopic cholecystectomy (LAP), total knee replacement (TKR), and total abdominal hysterectomy (TAH). The need for these surgeries is expected to rise in view of ageing populations. The exception is TAH, which is being replaced by minimally invasive laparoscopic hysterectomy (Gale et al. 2016). Studies have shown that a number of factors influence LOS following surgical procedures. These include patient characteristics - age, gender and body mass index for TKR (Jonas et al. 2013), TAH (Toma, Hopman & Gorwill 2004) and LAP (Ivatury, Louden & Schwesinger 2011). Indeed, the scrutiny on greater efficiency and financial sustainability has pushed for utilizing evidenced based tools such as enhanced recovery after surgery (ERAS), which influences surgical care time and complications (ERAS 2016). Studies have investigated the impact of implementing ERAS on LOS, which is reduced following implementation (Wijk et al. 2014) (Thiele et al. 2015, Keller et al. 2014, Miller et al. 2014, Aarts et al. 2012). However, ERAS' adaptation and implementation has been slow due to poor evidence from outcome data, difficulty bringing multidisciplinary groups together, resistance to change at the institutional level (Kehlet, Wilmore 2008), and little evidence outlining cost-effectiveness (Lee et al. 2014). So, while ERAS protocols address care pathways through a focus on clinical operative factors, other patient and health system factors are not directly considered which explains the lower stakeholder involvement and adoption. This research aims to fill this gap by considering criteria beyond the traditional medical ones. This study aims to develop a holistic model for deriving LOS, which incorporates multiple criteria – such as clinical medical, social, financial and risk and engages concerned stakeholders. Additionally, this study demonstrates the application of multi-criteria decision-making in real life to scientifically assess the best LOS policy alternative for three surgical procedures in a public hospital in Malta through the use of actual patient outcome data and engagement of multidisciplinary stakeholders' (e.g. surgeon, patient or patients' relatives, hospital management and other medics) perspectives.

The remainder of the paper is organized as follows. Section 2 demonstrates in detail the methodology and the model for deriving LOS for specific intervention along with the application. Section 3 discusses the contributions of the proposed approach while Section 4 concludes the study.

METHODOLOGY AND RESULTS

Setting

The health system in Malta is based primarily on a publicly-funded national health system, which is supplemented by the private sector. In 2012, the national average LOS for all causes in acute hospitals was 5.3 days while the national bed occupancy rate was 83.2% (World Health Organization 2005). The public hospital in this study is a 250,000m^2 complex with 827 beds and 25 operating theatres. The remainder of this section will outline the five steps to develop a holistic model for deriving the best policy alternative for patient LOS.

Step 1: Developing the decision model on LOS for specific interventions

The conceptual model applied was developed through extensive literature review, as well as consultation with key stakeholders (e.g. surgeons and other medical doctors, nurses and allied professions, patient or patients' relatives, hospital management) through focus groups, after which criteria and sub-criteria considered for analysis were mapped out. As described by Schorr (Schorr 2012) factors that influence LOS can be grouped into three broad categories - Patient, social and family environment, Clinical caregiver and Health care system (Table 1):

INSERT TABLE 1

Each focus group consisted of a mean of nine health care and hospital management professionals. The participants, who were presented with information derived from the literature review, provided their feedback, leading to the final criteria and sub-criteria of the model (Figure 1). Medical, Financial, Social and Risk are considered as criteria. Type of surgical intervention, likely condition of patient post-surgery, and expected outcomes are identified as medical sub-criteria. The sub-criteria - cost / benefit, capital and operating cost are considered within financial criteria. Patient satisfaction, community care provision, and family support are identified as sub-criteria for social criteria, and risk criteria are covered through readmission chance, possible discomfort, and likelihood of adverse event.

INSERT FIGURE 1

LOS policy alternatives (policy A – stringent target, Policy B – Moderate target, Policy C – Lenient target) were then developed based on patient data of the hospital under study available from January to December 2011. A random sample of 360 patients – 120 patients per procedure - from the hospital's patient administration system was extracted. Of the 120 patients, who underwent a TKR, five files were not available. Of the 120 patients, who underwent LAP, 8 files were unavailable, 9 were incorrectly coded, 8 were converted to open cholecystectomy and 1 non-show patient. Of the 120 TAH patients, 4 files were unavailable. Therefore, the final sample was 325 patients (90.3%). This patient data were analyzed to derive the current average LOS for each procedure (Figure 2):

INSERT FIGURE 2

Using these current ranges for the LOS for each surgery, three policy alternatives were outlined. Basing on the above displayed distributions, cut off points for each LOS range were developed for each procedure under analysis outlining the policy alternatives from the patient data. The data for each procedure were split into three cut points, each containing 33% of the respective sample. These uniform cut-off points based on the data distribution then delineated the policy ranges for the LOS to be analyzed. This methodology was chosen since it could be applied uniformly across all three procedures. Furthermore, this method considered the entire LOS range including extremes, thus ensuring that the LOS policy alternatives reflected the true range of LOS's for each procedure. The policy alternatives are illustrated in Table 2.

INSERT TABLE 2

The analytical tool was selected to scientifically fit the three interventions being studied. The complexity of hospital LOS demanded that flexibility of the tool needed to address the multi-criteria hierarchical structure, while incorporating both quantitative and qualitative multi-stakeholder perspectives (Pauly 2011). With this in mind, we chose a multiple criteria decision-making method for model building and data analysis involving two procedures. The first is using the Analytical Hierarchical Process (AHP), a multiple criteria decision-making technique developed by Saaty (Saaty 1994, Saaty 1977) for the verbal subjective judgements on prioritizing the four predictors of surgical LOS – medical, financial, social and risk. The AHP has been extensively utilized in different fields and for various situations (Saaty, Sodenkamp 2008). The mathematical underpinning of the AHP has been described in the Appendix. As shown by Saaty and Vargas (Saaty, Vargas 2006), the AHP can incorporate expert clinical judgment with statistical data so as to develop the best alternatives for decision-making. The steps for applying the AHP are as follows: development a hierarchical model with goal for decision-making, criteria and sub-criteria, and decision alternatives with the involvement of the concerned stakeholders; pairwise comparison of criteria using verbal scale as indicated in figure with the involvement of the concerned stakeholders to derive importance of criteria; deriving the relative preference of the alternative decisions by comparing each alternative pairwise; and synthesizing the results across the hierarchy to derive the overall priority vectors of the decision alternatives.

The second procedure involved pairwise comparisons of the sub-criteria under each criterion in line with the interventions – the objective data of which are obtained from the patients' files. In this part, we could not apply AHP as the sub-criteria were not scored through verbal judgements. Therefore, only pairwise comparisons of objective scores for the sub-criteria were employed (c.f. Supplementary file provides details of the coding used for data collected for patients who underwent laparoscopic cholecystectomy as an example, together with the anonymized data set so as to provide visibility of computation of values for the sub-criteria).

The multi-criteria decision-making method structures problems in the form of a hierarchy, mainly goal, criteria, and alternatives (Bernasconi, Choirat & Seri 2010). By using pairwise comparisons, ratio scales are calculated, providing numeric scales. There are other methods (e.g. analytic network process, fuzzy theory, multiple attribute utility theory and value theory, and The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)) that could have been adopted. However, this method seems to be the most appropriate one due to the characteristics of the criteria and decisions that are to be made, as well as the user friendliness of the method and easy to adopt with the existing practices.

Step 2: Model application and determining importance of criteria

The three surgical procedures considered are laparoscopic cholecystectomy (LAP), total knee replacement (TKR), and total abdominal hysterectomy (TAH). Table 3 describes the three procedures and includes the number of procedures conducted within the hospital under study in 2011.

INSERT TABLE 3

In this step, pairwise comparison using verbal scale as per AHP method is used. The higher order criteria outlined in the model – medical, financial, social and risk – are the common vectors and are applied to all policies. The sub-criteria are policy specific vectors and vary depending on the procedure. To develop a total policy rating for each alternative policy, the common and policy specific vectors were derived. The common criteria vectors were calculated using expert verbal judgment of preference assigned by the members of the focus group for pairwise comparison. The importance of criteria (policy vectors) as derived from the pairwise comparison is – Medical (0.533), Risk (0.260), Social (0.105) and Financial (0.102). The importance of all the sub-criteria is derived through pairwise comparison (c.f Supplementary file). Subsequently, preference of each alternative decision is derived through pair wise comparison with respect to each sub-criteria. All the above pair wise comparisons matrixes are shown in the Appendix for the three interventions. Finally, the importance of all the criteria and sub-criteria is synthesized along with the preference of three alternatives with respect to each sub-criterion that results the overall ranking of the decision alternatives for three interventions. After applying the conceptual model to each intervention (c.f. Supplementary File), the best policy alternatives for each procedure are outlined in Table 4. The policy with the highest ratio score is considered the best policy alternative.

INSERT TABLE 4

Step 3: Gathering data on each sub-criterion for specific policy and comparing the best policy alternatives to present patient data

In this step, the sub-criteria based on coded objective data from the patients' files (c.f. Supplementary file) were analyzed.

Laparoscopic Cholecystectomy

The current average LOS for LAP in the hospital under study is 2.2 days, which is within the best policy alternative of less than 3 days as derived from the applied model.

Total Knee Replacement

The current average LOS for TKR in the hospital under study is 6.61 days, which is above the best policy alternative of ≤ 4 days. Since the present average LOS is above the alternative, univariate analysis was conducted to assess possible differences between patients falling within the three policy alternatives. Mann Whitney U, Kruskall Wallis H and Spearman's Correlation tests were used (Table 5).

INSERT TABLE 5

The results show that those with a longer LOS were older ($p<0.05$) however were more independent ($p<0.01$) which may reflect broader social support needs of patients as this age, something which may impact upon recovery. This raises the issue that for the hospital to function effectively, it must be adequately supported by the entire health and social systems. Indeed, in areas such as acute rehabilitation, external services and social support are crucial to enable surgeons to adopt the appropriate LOS policy. Apart from this however, patients with longer LOS were similar to those with shorter LOS across various clinical and demographic characteristics.

In monetary terms, a shift of the average LOS to 4 days from 6.61days would equate to considerable yearly savings. The estimated cost per surgical bed night for Orthopedics in the hospital is €191.12 (TOM 2012). For 467 procedures in 2011 with an average number of bed nights per procedure at 6.61 days, the hospital dedicates on average 3086.87 bed days for TKRs. In monetary terms this would equal €589,963 spent annually on occupied bed days. Should the alternative best policy be affectively implemented, we can expect the total average number of bed days for TKRs to be 1868 equal to an annual cost of €357,012. This indicates an annual saving of €232,951 from LOS reduction in TKRs alone.

Total Abdominal Hysterectomy:

The current average LOS for TAH in the hospital under study is 6.61 days, which is above the best policy alternative of less than or equal to 4 days. To investigate possible differences between patients falling within the three policy alternatives, univariate analysis was also conducted. Mann Whitney U, Kruskall Wallis H and Spearman's Correlation tests were used (Table 6).

INSERT TABLE 6

The results revealed that patients suffering from cancer had a longer LOS ($p<0.05$). While this is expected, this result raises the issue that management should support clinicians in one-to-one clinical decisions when treating patients with unique demands. When excluding patients who had cancer as an indication for surgery, there were no differences in patients' features across the three policy alternatives.

Therefore, notwithstanding any patient specific clinical decisions, the best policy alternative is a benchmark that can be applied across patients undergoing a TAH.

Similar to TKRs, a shift of the average LOS to 4 days from 6.11 days for TAH would equate to considerable yearly savings. For 480 procedures in 2011 with an average LOS of 6.11 days, the hospital dedicates on average 2932.8 bed days for TAHs. The estimated cost of a bed in gynecology is €179.10(TOM 2012). In monetary terms this would equal €525,265 spent annually on occupied bed days. Should the alternative best policy be affectively implemented to reduce the average LOS to a maximum of 4 days, we can expect the total average number of bed days for TKRs to be 1920 equal to an annual cost of €343,872. This indicates an annual saving of €181,393 from LOS reduction in TAH alone.

Step 4: Benchmarking policy alternatives against international standards

The maximum for the best policy alternative and present average LOS for each intervention were compared with international benchmarks (Figure 3).

INSERT FIGURE 3

The average LOS for LAP for the UK (NHS 2015) also fits within the best policy alternative range derived from the model and is similar to what is being experienced in Malta. For TKR and TAH, we found more comparative statistics for LOS. The average LOS for TKR for Finland, Canada and the United States (Cram et al. 2012) are within the best policy alternative range derived from the model. This is similar for TAH which compared well to the benchmarks for LOS for the UK (NHS 2015), Denmark (Lykke et al. 2013) and the United States (Warren et al. 2009). For both these procedures, the present patient data show that the average LOS in Malta is above the averages experienced in these countries. Comparing the derived alternatives from our model with international benchmarks suggests that the alternatives outlined in this study are realistic targets.

Step 5: Actions for implementation of model

The multi-criteria decision-making based framework for deriving LOS for specific interventions is a unique approach to deciding upon the best policy alternative for LOS within hospital because it incorporates evidence from the literature, as well as site-specific quantitative patient data and qualitative stakeholder's perspectives. Furthermore, it allows for an in-depth analysis of patient characteristics, an important factor to consider when the average LOS is outside the best policy range. This ensures a better understanding of any system-level deficiencies, which may need to be addressed before adopting the best policy alternative.

While the flexibility of the model allows for it to be adopted effectively in any setting and for any intervention, its implementation requires a number of things to be in place. Firstly, all stakeholders need to be onboard to contribute to the development of the criteria while also being amenable to implementing the policy alternative that the model derives. Secondly detailed patient data are important to allow for the quantitative and analytical component of the model to be applied within the setting being studied. Data are also important for economic assessment of the possible gains to be made by implementing the policy alternative.

DISCUSSION:

Hospital LOS is an important measure of quality and efficiency within hospitals and recent emphasis has been put on reducing LOS across countries. Some health care settings have adopted surgical protocols such as ERAS with the aim of improving post-surgical outcomes. While such protocols show a measure of improvement in LOS, implementation and adaptation has been slow as focus still remains on clinical care factors. Without a comprehensive multi-criteria decision-making model that engages all stakeholders, ownership and adoption of policies and protocols may not be sustainable. A paradigm shift is therefore needed to ensure that decisions are made based on a strong evidence base; moving away from decisions that are arbitrarily taken by individual clinicians (Hollnagel, Braithwaite & Wears 2013). This study has developed and applied a holistic model to determine optimal LOS. It outlines four major criteria to consider when developing LOS benchmarks within hospitals – medical, social, financial and risk. The model shows how health managers and clinicians need to consider all four criteria when determining the best policy alternative to ensure a balance rather than a trade-off between health care quality, efficiency, costs and LOS. The application of the model through an objective analytical tool yielded three policy alternatives for the surgical procedures considered which compare well with the average LOS found at country level internationally.

When considering the complexity of the health system and its impact on LOS, the most appropriate policy alternative would help achieve financial sustainability without compromising on other important healthcare outcomes. With the implementation of the highest rated policy alternative therefore; we can expect an increase in cost effectiveness, efficiency and a faster release in beds. When considering the two procedures, which demonstrated a present average LOS above the best policy alternative, implementation of the policy alternative could lead to a considerable reduction in costs. The estimated annual savings would be that of €414,344 for the hospital from LOS reduction in TKR and TAH alone. If this is extrapolated to so many other procedures that are carried out in the hospital, the savings could potentially run into millions annually.

However, one must not forget that the hospital does not function in isolation and this study shows that it must be supported system-wide by both health and social policy sectors. Decisions about LOS should also include the unique demands of individual patients. While the methodology ensures that stakeholders' perspectives are considered, the judgment of the clinician with respect to specific individual patients' needs must always be taken into account. This study has shown that the current LOS for two out of the three procedures fall short of the best policy alternative and this may be indicative of pervasive contextual factors within the hospital system. However, when excluding these factors; the policy alternative outlined is generalizable across patients. A limitation of this study is the lack of patient level financial data, which would provide a richer analysis of the financial sub-criteria. On the other hand, a major strength is the large randomly-selected patient sample, as well as the application across three surgical procedures.

CONCLUSION

Multi-criteria decision-making tools enable management to optimize resource use, through the application of a scientific management technique with the involvement of all relevant stakeholders. The model developed and applied is flexible and can be adopted across different settings. It allows for the development of context specific criteria, ranked and scored based on stakeholder preferences and objective statistical data. Future studies can apply this method to other interventions across health care settings to demonstrate its applicability within the broader healthcare context.

Compliance with Ethical Standards:

Funding: The project was not externally funded.

Conflict of Interest: Authors declare that they have no conflict of interest.

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

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Figure 1: Framework for AHP, identifying goal, criteria, sub-criteria and alternative policies

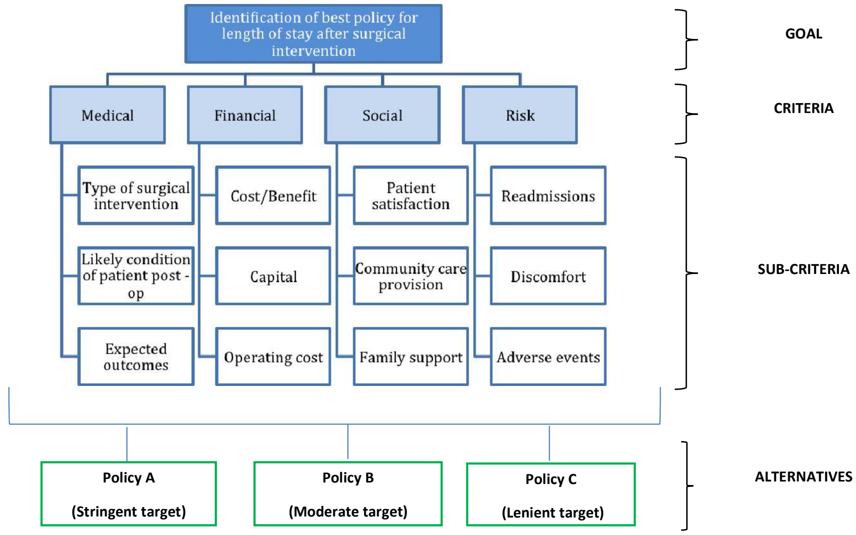


Figure 2: Distribution of length of stay for the three procedures TKR, TAH and LAP in hospital under study

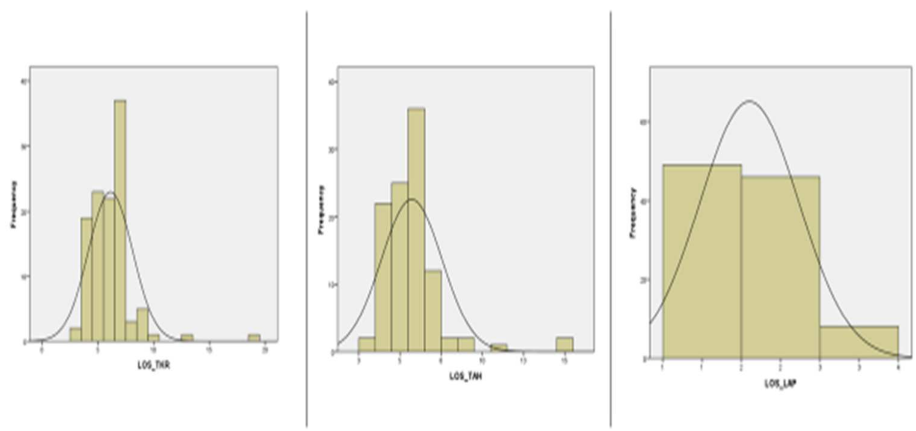
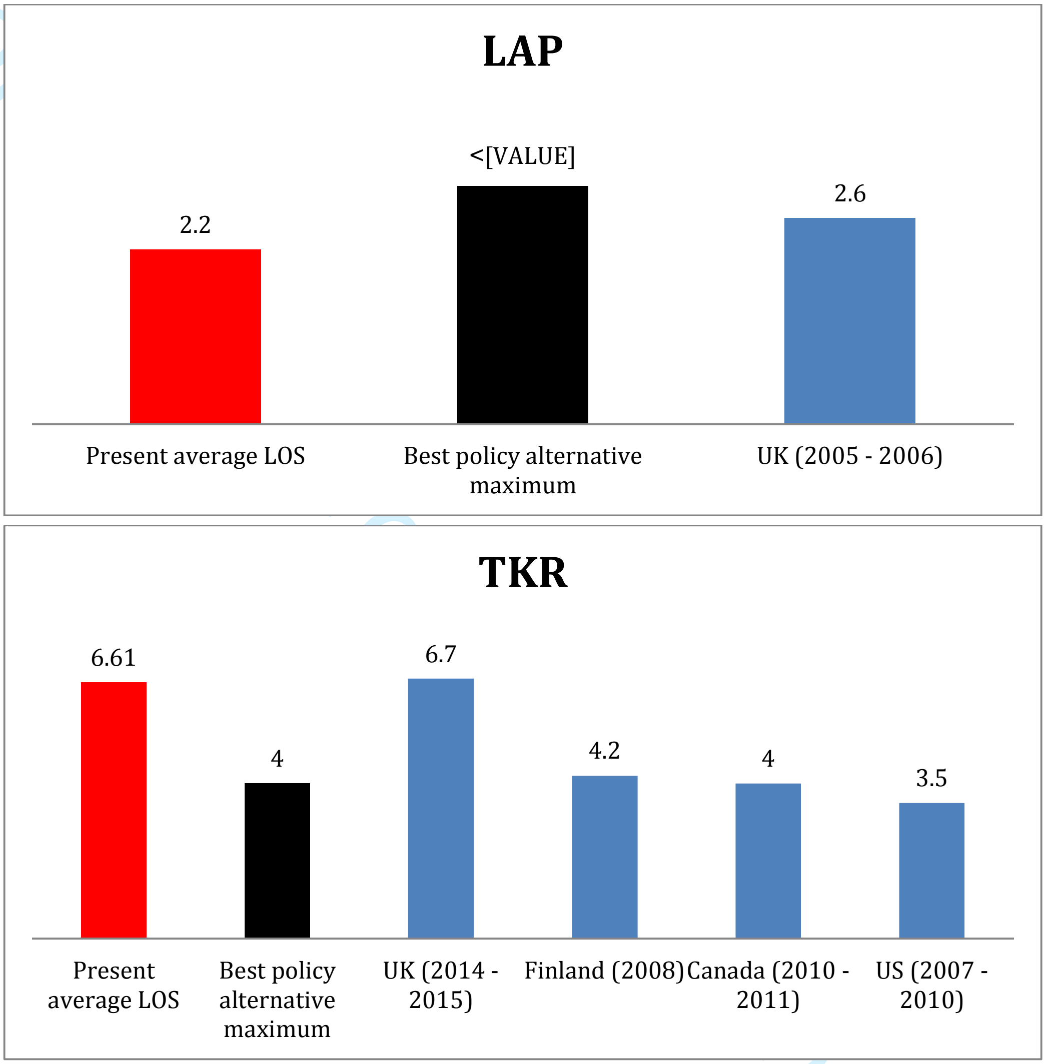


Figure 3

Charts showing ALOS in hospital under study, compared to best alternative using the multi-criteria decision making method and compared with statistics from other countries for TKR, AHP and LAP



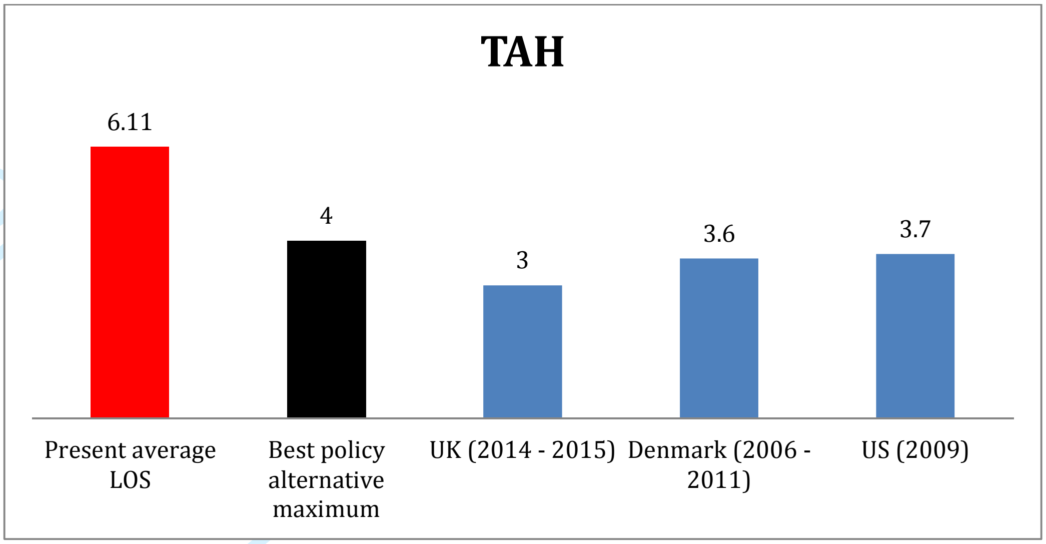

TAH
6.11
4
3
3.6
3.7
Present average LOS
Best policy alternative maximum
UK (2014 - 2015)
Denmark (2006 - 2011)
US (2009)

Figure 4: Summary of methodology presented in this study.

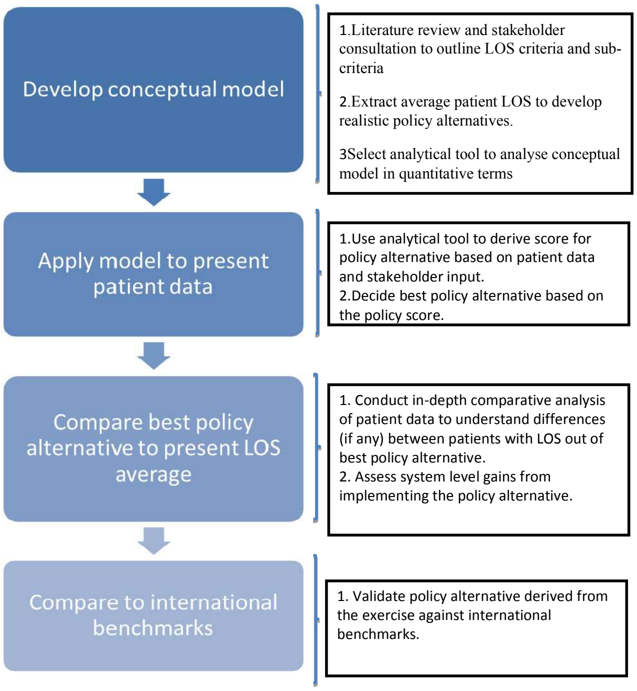


Table 1
Factors that influence length of stay adapted from Schorr (Schorr 2012)

Factor	Overview
Patient, social and family environment	• Predisposing factors for example age and gender • Enabling factors: availability of social and financial support • Vulnerability factors: multiple pathology and dependency (Rambani, Okafor 2008).
Clinical caregiver	• Dependence on physicians' medical decisions (2013)
Health care system	• Admitting services and availability of beds, human resources and technology • Efficiency of supporting services, clinical pathways; and long-term and palliative care facilities.

Table 2
Policy alternative options for TKR, TAH and LAP

		Policy A – Stringent	**Policy B - Moderate**	**Policy C - Lenient**
Procedure	***LAP***	LOS < 3 days	3≤ LOS ≤ 4 days	LOS > 4days
	TKR	LOS ≤ 4 days	4 < LOS ≤ 7 days	LOS > 7 days
	TAH	LOS ≤ 4 days	4< LOS ≤ 7 days	LOS > 7 days

TKR=Total Knee Replacement; TAH=Total Abdominal Hysterectomy; LAP=Laparoscopic Cholecystectomy

Table 3: Description of the three procedures under study

Procedure	**Description**	**Number of procedures conducted in hospital under study in 2011**
Laparoscopic cholecystectomy (LAP)	The removal of the gall bladder using a laparoscope, categorized as a major surgery	208
Total knee replacement (TKR)	The entire knee joint is replaced, categorized as a major surgery	467
Total abdominal hysterectomy (TAH)	The uterus and cervix are removed through an incision in the abdomen, categorized as a major surgery	480

Table 4: Best policy alternative derived from the analysis (workings in supplementary file, SHEET 3)

Procedure	Policy Ratio Scores	Best policy alternative
LAP	Policy A – 0.38 Policy B – 0.33 Policy C – 0.29	Policy A – Stringent Target LOS ≤ 3
TKR TAH	Policy A – 0.36 Policy B – 0.33 Policy C – 0.31	Policy A – Stringent Target LOS ≤ 4 days
	Policy A – 0.36 Policy B – 0.33 Policy C – 0.31	Policy A – Stringent Target LOS ≤ 4 days

LAP=Laparoscopic Cholecystectomy; TKR=Total Knee Replacement; TAH=Total Abdominal Hysterectomy.

Table 5: Results of univariate analysis comparing patients within the three policy alternatives for TKR across a number of characteristics

		Mean Rank	*p-value*
Gender	Male	58.91	0.788
	Female	57.06	
Post-op Mobility	Independent	59.52	**0.001****
	Crutches	57.24	
	Zimmer frame	31.93	
Re-admitted post-op	No	36.69	0.833
	Yes	35.30	
Availability of family support	No	52.56	0.100
	Yes	39.16	
		Spearman's Rho	*p-value*
Age (years)		.226	**0.016***
Days till mobilization		.105	0.289
Number of comorbidities		.059	0.543

** Significant at the 0.01 level; *significant at the 0.05 level

Table 6: Results of univariate analysis comparing patients within the three policy alternatives for TAH across a number of characteristics

		Mean Rank	*p-value*	*p-value (excluding cancer patients)*
Cancer as indication for surgery	Yes	74.00	**.015***	**-**
	No	50.79		
Co-morbidities	Yes	54.49	.993	.948
	No	54.55		
Re-admitted post-op	Yes	42.40	.415	.375
	No	53.01		
		Spearman's Rho	*p-value*	*p-value (excluding cancer patients)*
Age (years)		.210	**.033***	.180

*Significant at the 0.05 level

Coding of Data for Patients with Laparoscopic Cholecystectomy

THE SCORES FOR MEDICAL, FINANCIAL, SOCIAL AND RISK AS CAPTURED FROM DATA FROM PATIENTS' FILES WERE THEN INPUTTED ON THE PAIRWISE COMPARISON SHEET

	MEDICAL				RISK				SOCIAL			FINANCIAL
Total LOS	**Co-morbidity**	**days post-op feeding**	**days post-op mobilization**	**Drain**	**Fever post op**	**Wound problems**	**vomiting post-op**	**Pain control**	**Age**	**Mobility pre-Op**	**Family Support**	**Days of hospitalisation**
< 3 days = Policy A	Two or more co-morbities = 1	0 days = 5	0 days = 5	Yes = 1	Yes = 1	Yes = 1	Yes = 1	Yes = 1	under 20 years = 5	No = 1	No = 1	least expensive = 3
3-4 days = Policy B	No or just 1 = 2	1 day = 4	1 day = 4	No = 2	No = 2	No = 2	No = 2	No = 2	21 - 40 years = 4	Yes =2	Yes = 2	moderately expensive = 2
> 4 days = Policy C		2 days = 3	2 days = 3						41-60 years = 3			most expensive = 1
		3 days = 2	3 days = 2						61-80 years = 2			
		4+ days = 1	4+ days = 1						81+ years = 1			
	Patients who suffered from 2 or more chronic conditions were at a higher risk of developing complications and this would have affected the LOS. These were given a Score of 1. Whereas patients who didn't suffer from any, or just 1, chronic condition were given a Score of 2.	Any patients who throughout their recovery in hospital needed post-op feeding were scored according to the number of days and assumed better score 5 for those not needing any to score of 1 for those needing more than 4 days.	Patients who were mobilised on the day of the operation were considered to have a fast recovery and were thus assigned a Score of 5. Further lower scores were given depending on days' post-op mobilisation	Any patients who needed a drain were deemed to need more medical attention and scored 1. Those who did not have a drain were scored 2.	Any patients who had fever were deemed to be more at risk and scored 1. Those who did not have a fever were scored 2.	Any patients who had wound problems for example infection were deemed to be more at risk and scored 1. Those who did not were scored 2.	Any patients who vomited were deemed to be more at risk and scored 1. Those who did not were scored 2.	Any patients who had good pain control were deemed to be more at risk and scored 1. Those who did not were scored 2.	The age of the patient was considered as part of the social criterion. Higher scores were given to younger age groups assuming less attention is needed from a social perspective.	Mobility pre-op was considered of an advantage and a predictor of less social problems post-op and scored 2. Those who had mobility problems pre-op were assumed to need more social support post-op and scored 1.	Family support was considered of an advantage and a predictor of less social problems post-op and scored 2. Those who had recorded problems with family support were assumed to need more social support from hospital post-op and scored 1.	The financial vectors for each policy: since no costing data was available, several assumptions needed to be made: it was concluded that each operation costs the same and the difference in expense resulted only from a longer LOS.

The Analytical Hierarchy Process by Thomas Saaty and Pairwise Comparisons for LOS Decision-making in Laparoscopic Cholecystectomy Surgery

Select the best policy

Medical	Financial	Social	Risk
Policy A	Policy A	Policy A	Policy A
Policy B	Policy B	Policy B	Policy B
Policy C	Policy C	Policy C	Policy C

1. Developing the decision model on LOS for specific intervention, using the Analytical Hierarchy Process (AHP): Verbal Judgement of Preference BY FOCUS GROUP using following ratings

		Numerical Rating
Extremely Preferred		9
	Very strong to extremely	8
Very strongly preferred		7
	Strongly to very strongly	6
Strongly preferred		5
	Moderately to strongly	4
Moderately preferred		3
	Equally to moderately	2
Equally preferred		1

Pairwise comparison matrix was carried out for each of the criteria (Medical, Financial, Social and Risk) after verbal (subjective) judgement of preference by focus group. This was done by crosswise division of each value, summation of the columns, dividing each value with the summed value and finally summation across the rows to provide the priority vector with respect to each criterion

Importance of Constructs

	Medical	Financial	Social	Risk	
Medical	1	7	4	2	**Medical is very strongly preferred to financial so the score is 7; Medical is moderately to strongly preferred to Social so the score is 4; Medical is equally to moderately preferred to Risk, so the score is 2.**
Financial	0.142857143	1	1	0.5	
Social	0.25	1	1	0.333333333	
Risk	0.5	2	3	1	
Summation of Columns	**1.892857143**	**11**	**9**	**3.833333333**	

Synthesising judgements

	Medical	Financial	Social	Risk	Priority vector
Medical	0.528301887	0.636363636	0.444444444	0.52173913	**0.533**
Financial	0.075471698	0.090909091	0.111111111	0.130434783	**0.102**
Social	0.132075472	0.090909091	0.111111111	0.086956522	**0.105**
Risk	0.264150943	0.181818182	0.333333333	0.260869565	**0.260**

2. Determining importance of the criteria: PAIRWISE COMPARISONS USING OBJECTIVE DATA FROM PATIENTS' FILES

Analysis of the coded objective data from the patient files. For each sub-criteria of each policy, we summed the total value for each sub-criterion (please refer to sheet 1 e.g. days post-op feeding and found the average value). Once all the values were obtained, they were added for each sub-criterion and then for each criterion.

	Policy A (Stringent target LOS < 2 days)	Policy B (Moderate target LOS 2-3 days)	Policy C (Lenient target LOS > 3 days)	Total for Each Criterion
Medical (co-morbidity; days post-op feeding; days post-op mobilisation; drain)	11.91	10.71	9.57	**32.19**
Financial (financial burden based on LOS assuming same costs for operastion regardless when carried out). The higher score reflects the lower financial burden)	3	2	1	**6**
Social (age; mobility pre-op; family support)	5.82	5.44	5.6	**16.86**
Risk (fever post-op; wound; vomiting post-op; pain control)	6.85	6.79	6.49	**20.13**

3. Gathering data on each sub-criterion for specific policy and synthesising values of each criterion in each policy	**This was done by dividing each value of each criterion with the total value for each crierion. Example 11.91/32.19=0.369990680335508**

	Policy A	**Policy B**	**Policy C**	**TOTAL**
Medical (co-morbidity; days post-op feeding; days post-op mobilisation; drain)	0.36999068	0.332712022	0.297297297	1
Financial (financial burden based on LOS assuming same costs for operastion regardless when carried out). The higher score reflects the lower financial burden)	0.5	0.333333333	0.166666667	1
Social (age; mobility pre-op; family support)	0.34519573	0.322657177	0.332147094	1
Risk (fever post-op; wound; vomiting post-op; pain control)	0.340288127	0.337307501	0.322404372	1

CRITERIA	**Priority Vectors from Step 1**	**Policy A VALUES**		**Policy B VALUES**		**Policy C VALUES**		**Total GP**
		LP	GP	LP	GP	LP	GP	
Medical	0.532712275	11.91	6.344603189	10.71	5.70534846	9.57	5.098056467	
Financial	0.101981671	3	0.305945012	2	0.203963341	1	0.101981671	
Social	0.105263049	5.82	0.612630944	5.44	0.572630986	5.6	0.589473074	
Risk	0.260043006	6.85	1.781294591	6.79	1.76569201	6.49	1.687679109	
		Summation of GP	**9.044473737**		**8.247634798**		**7.47719032**	**24.76929885**
		Division of Policy GP on Total GP example for Policy A= 9.04447373 7/24.769298 8540035=0. 3651485570 84942	**0.365148557**		**0.332978129**		**0.301873314**	

		PRIORITY A		**PRIORITY B**		**PRIORITY C**	
CRITERIA	**Priority Vectors from Step 1**	**Policy A VALUES**		**Policy B VALUES**		**Policy C VALUES**	
		LP	GP	LP	GP	LP	GP
Medical	0.532712275	0.36999068	0.197098577	0.332712022	0.177239778	0.297297297	0.158373919
Financial	0.101981671	0.5	0.050990835	0.333333333	0.03399389	0.166666667	0.016996945
Social	0.105263049	0.34519573	0.036336355	0.322657177	0.033963878	0.332147094	0.034962816
Risk	0.260043006	0.340288127	0.088489547	0.337307501	0.087714457	0.322404372	0.083839002
PRIORITY RATING OF			**0.372915315**		**0.332912003**		**0.294172682**

This means that according to the AHP analysis (subjective verbal judgements on setting priorities between Medical, Financial, Social and Risk Criteria) and further pairwise comparisons of sub-criteria (obtained from objective data from patients' files) , the best policy for laparoscopic cholecystectomy is the stringent policy, with a length of stay of less than 2 days.

	Policy Vectors	
Laparoscopic Cholecystectomy	Policy A – 0.38	Policy A – Moderate Target LOS ≤ 3
	Policy B – 0.33	
	Policy C – 0.29	

LAPARASCOPIC CHOLECYSTECTOMY

Deriving best policy on LOS

Importance of Constructs

	Medical	**Financial**	**Social**	**Risk**
Medical	1	7	4	2
Financial	0.14285714	1	1	0.5
Social	0.25	1	1	0.33333333
Risk	0.5	2	3	1
	1.892857143	11	9	3.833333333

	Medical	Financial	Social	Risk	**Priority vector**
Medical	0.528301887	0.636363636	0.444444444	0.52173913	**0.533**
Financial	0.075471698	0.090909091	0.111111111	0.130434783	**0.102**
Social	0.132075472	0.090909091	0.111111111	0.086956522	**0.105**
Risk	0.264150943	0.181818182	0.333333333	0.260869565	**0.260**
					1

	Policy A	**Policy B**	**Policy C**		**Policy A**	**Policy B**	**Policy C**	
Medical	11.91	10.71	9.57	32.19	0.37	0.33	0.30	1.00
Financial	3	2	1	6	0.50	0.33	0.17	1.00
Social	5.82	5.44	5.6	16.86	0.35	0.32	0.33	1.00
Risk	6.85	6.79	6.49	20.13	0.34	0.34	0.32	1.00

		Policy A		**Policy B**		**Policy C**		
		LP	GP	LP	GP	LP	GP	
Medical	0.533	11.91	6.34460318	10.71	5.70534846	9.57	5.098056467	
Financial	0.102	3	0.30594501	2	0.203963341	1	0.101981671	
Social	0.105	5.82	0.61263094	5.44	0.572630986	5.6	0.589473074	
Risk	0.260	6.85	1.78129459	6.79	1.76569201	6.49	1.687679109	
			9.04447373		8.24763479		7.47719032	24.7692988
			0.36514855		0.33297812		0.30187331	

		Policy A		**Policy B**		**Policy C**	
		LP	GP	LP	GP	LP	GP
Medical	0.533	0.37	0.197098577	0.33	0.177239778	0.30	0.158373919
Financial	0.102	0.50	0.050990835	0.33	0.03399389	0.17	0.016996945
Social	0.105	0.35	0.036336355	0.32	0.033963878	0.33	0.034962816
Risk	0.260	0.34	0.088489547	0.34	0.087714457	0.32	0.083839002
Priority rating			**0.372915**		**0.332912**		**0.2941726**

OTAL KNEE REPLACEMENT

Deriving best policy on LOS

Importance of Constructs

	Medical	**Financial**	**Social**	**Risk**
Medical	1	7	4	2
Financial	0.142857143	1	1	0.5
Social	0.25	1	1	0.333333333
Risk	0.5	2	3	1
	1.892857143	11	9	3.833333333

	Medical	Financial	Social	Risk	**Priority vector**
Medical	0.5283018	0.63636363	0.44444444	0.52173913	**0.533**
Financial	0.0754716	0.0909090	0.1111111	0.1304347	**0.102**
Social	0.1320754	0.0909090	0.1111111	0.0869565	**0.105**
Risk	0.2641509	0.1818181	0.3333333	0.2608695	**0.260**
					1

	Policy A	**Policy B**	**Policy C**		**Policy A**	**Policy B**	**Policy C**	
Medical	4.61	4.55	4.44	13.6	0.34	0.33	0.33	1.00
Financial	3	2	1	6	0.50	0.33	0.17	1.00
Social	1.05	1.02	0.93	3	0.35	0.34	0.31	1.00
Risk	7.15	7.08	7.09	21.32	0.34	0.33	0.33	1.00

		Policy A		**Policy B**		**Policy C**		
		LP	GP	LP	GP	LP	GP	
Medical	0.533	4.61	2.4558035	4.55	2.4238408	4.44	2.3652424	
Financial	0.102	3	0.3059450	2	0.2039633	1	0.1019816	
Social	0.105	1.05	0.1105262	1.02	0.107368	5.6	0.5894730	
Risk	0.260	7.15	1.8593074	7.08	1.8411044	6.49	1.6876791	
			4.7315822		4.5762769		4.7443763	14.052235
			0.3367138		0.3256618		0.33762431	

		Policy A		**Policy B**		**Policy C**	
		LP	GP	LP	GP	LP	GP
Medical	0.533	0.34	0.1805737	0.33	0.1782235	0.33	0.17391489
Financial	0.102	0.50	0.0509908	0.33	0.033993	0.17	0.01699694
Social	0.105	0.35	0.0368420	0.34	0.0357894	0.31	0.03263154
Risk	0.260	0.34	0.0872095	0.33	0.0863557	0.33	0.08647771
Priority rating			**0.3556162**		**0.3343626**		**0.3100210**

TOTAL ABDOMINAL HYSTERECTOMY

Deriving best policy on LOS

Importance of Constructs

	Medical	**Financial**	**Social**	**Risk**
Medical	1	7	4	2
Financial	0.142857143	1	1	0.5
Social	0.25	1	1	0.333333333
Risk	0.5	2	3	1
	1.892857143	11	9	3.8333333

	Medical	Financial	Social	Risk	**Priority vector**
Medical	0.528301887	0.6363636	0.4444444	0.52173913	**0.533**
Financial	0.075471698	0.0909090	0.1111111	0.1304347	**0.102**
Social	0.132075472	0.0909090	0.1111111	0.0869565	**0.105**
Risk	0.264150943	0.1818181	0.3333333	0.2608695	**0.260**
					1

	Policy A	**Policy B**	**Policy C**		**Policy A**	**Policy B**	**Policy C**	
Medical	14.72	14.42	13.2	42.34	0.35	0.34	0.31	1.00
Financial	3	2	1	6	0.50	0.33	0.17	1.00
Social	2	1.37	1.79	5.16	0.39	0.27	0.35	1.00
Risk	5.03	5.29	5.73	16.05	0.31	0.33	0.36	1.00

		Policy A		**Policy B**		**Policy C**		
		LP	GP	LP	GP	LP	GP	
Medical	0.533	14.72	7.8415246	14.42	7.6817109	13.2	7.0318020	
Financial	0.102	3	0.3059450	2	0.2039633	1	0.1019816	
Social	0.105	2	0.2105260	1.37	0.1442103	5.6	0.5894730	
Risk	0.260	5.03	1.3080163	5.29	1.3756275	6.49	1.6876791	
			9.6660121		9.4055122		9.4109358	28.482460
			0.3393671		0.3302212		0.3304116	

		Policy A		Policy B		Policy C	
		LP	GP	LP	GP	LP	GP
Medical	0.533	0.35	0.1852037	0.34	0.1814291	0.31	0.1660794
Financial	0.102	0.50	0.0509908	0.33	0.0339938	0.17	0.0169969
Social	0.105	0.39	0.0407996	0.27	0.0279477	0.35	0.036515
Risk	0.260	0.31	0.0814963	0.33	0.0857088	0.36	0.0928377
Priority rating			**0.3584905**		**0.3290796**		**0.3124298**

Appendix A

One of the widely used Multi-Criteria Decision Making (MCDM) techniques is the AHP due to the ability of the Decision Maker (DM) to provide the pairwise comparisons between multiple objectives. Pairwise comparison (a_{ij}) are introduced in the hierarchy matrix (A), for the relative importance between criteria *i* and *j* for $i > j$. The reciprocals are calculated for $i < j$ such that $a_{ji} = a_{ij}^{-1}$ while a_{ij} equals 1 for $i = j$. In order to derive the weights of the alternatives, the eigenvector corresponding to the maximum eigenvalue (λ_{max}) is calculated in (1).

$$AW = \lambda_{max} W$$

A measure of the consistency of the hierarchy matrix A is given by the consistency ratio *CR*, defined in (2) where *CI* is the Consistency Index (*CI*) defined in (3) while *RI* is a Random Index which is a fixed value for a $n \times n$ dimensional hierarchy matrix A; *RI* can be interpreted as the average consistency index for random comparisons for a matrix of the same size. A low value of *CR* (below 10%) indicates consistency. For more detail on how the AHP works the interested reader is referred to (Saaty, 1996)

$$CR = \frac{CI}{RI}$$

$$CI = \frac{\lambda_{max} - n}{n-1}$$

~~Decision-making on p~~Post-surgery length of stay using ~~the Analytic Hierarchy Process~~multi-criteria decision-making tool

Abstract

Purpose – Length of stay (LOS) in hospital after surgery varies for each patient depending on surgeon's decision that considers criticality of the surgery, patient's conditions before and after surgery, expected time to recovery and experience of the surgeon involved. Decision on patients' LOS at hospital post-surgery affects overall healthcare performance as it affects both cost and quality of care. The main purpose of this research is to develop a model for deriving the most appropriate length of stay after surgical interventions.

Design/methodology/approach – The study adopts an action research involving multiple stakeholders (Surgeon, patients / patients' relatives, hospital management and other medics). Firstly, a conceptual model is developed using literature and experts' opinion. Secondly, the model is applied in three surgical interventions in a public hospital in Malta to demonstrate the effectiveness of the model. Thirdly, the policy alternatives developed are compared to a selection of current international standards for each surgical intervention. The proposed model analyses three LOS threshold policies for three procedures using efficiency and responsiveness criteria. The entire analysis is carried out using 325 randomly selected patient files along with structured interactions with more than 50 stakeholders (Surgeon, patients / patients' relatives, hospital management and other medics). ~~The Analytic Hierarchy Process (AHP),~~ A~~a~~ multiple criteria decision-making method is deployed for model building and data analysis. The method involves combining the Analytic Hierarchy Process (AHP) for verbal subjective judgements on prioritizing the four predictors of surgical LOS – medical, financial, social and risk, with pairwise comparisons of the sub-criteria under each criterion in line with the concerned interventions – the objective data of which are obtained from the patients' files. ~~for model building and data analysis.~~

Findings – ~~The group identified four predictors of surgical LOS – medical, financial, social and risk and several sub-criteria under each criterion in line with the concerned interventions.~~ The proposed model, was successfully applied to decide on the best policy alternative for LOS for the three interventions. The best policy alternatives compared well to current international benchmarks.

Research limitations/implications – The proposed method needs to be tested for other interventions across various healthcare settings.

Practical implications – Multi-criteria decision-making tools enable resource optimization and overall improvement of patient care through the application of a scientific management technique that involves all relevant stakeholders, while utilizing both subjective judgements as well as objective data.

Originality/value – Traditionally, the duration of post-surgery LOS is mainly based on the surgeons' clinical but also arbitrary decisions, with as a result, having insufficiently explicable variations in LOS amongst peers for similar interventions.

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~~This research presents a decision-making model using the Analytic Hierarchy Process (AHP) to derive LOS for specific interventions with the involvement of multiple stakeholders (e.g. surgeon, patient or patients' relatives, and other medics) and considering financial, social and risk criteria apart from clinical factors.~~ According to the authors' knowledge this is the first attempt to derive post-surgery LOS using the AHP~~, –~~ a multiple criteria decision-making method.

Keywords – Analytic Hierarchy Process, Hospital, Length of stay, ~~-~~ Multi-criteria decision-making, Multiple stakeholders

INTRODUCTION

Hospitals represent the highest proportion of health care expenditure (Organization for Economic Cooperation and Development (OECD) Staff 2013), which is expected to rise with increasing ageing populations (Bloom et al. 2011, Pammolli, Riccaboni & Magazzini 2012). Over the past decade, the European Commission (EC) has acknowledged the need to monitor health systems' performance. Indeed, EC's country-specific recommendations (CSRs) on health systems within the European Semester, focus on curtailing public spending through reduction in hospital beds and in-patient days, as well shifting from inpatient to daycare and primary care (Azzopardi-Muscat et al. 2015). Inappropriate admissions and prolonged LOS are among the leading sources of hospitals' inefficiences (Etienne, Asamoa-Baah & Evans 2010). Optimal decisions in this area can reap substantial cost benefits by enhancing patients' satisfaction and reducing cost. Hospital LOS is expected to vary between countries, hospitals, and across settings, due to variability in procedures and practices. What remains consistent worldwide, is the target of reducing LOS (Organization for Economic Cooperation and Development (OECD) Staff 2013, Clarke, Rosen 2001), though this is not a straightforward undertaking. While a shorter stay will decrease the cost per discharge (Organization for Economic Cooperation and Development (OECD) Staff 2013)(Organization for Economic Cooperation and Development (OECD) Staff 2013), a short LOS may be associated with adverse health outcomes and higher readmission rates, thereby increasing costs per illness episode (Husted, Holm & Jacobsen 2008). On the other hand, a prolonged LOS not only increases costs, but is also associated with adverse events and complications (Senthilkumar, Ramakrishnan 2012, Lim et al. 2006). Therefore, the right balance must be found between ensuring healthcare quality and cost-saving. Improvements in LOS could release capacity by way of beds and staff time (NHS 2008). However understanding the complexity of factors underlying LOS is crucial before one pushes forward realistic targets.

Surgical procedures present major challenges to hospital management and financing (Losina et al. 2012). This study investigates the best LOS policy alternatives after three procedures - laparoscopic cholecystectomy (LAP), total knee replacement (TKR), and total abdominal hysterectomy (TAH)~~ and laparoscopic cholecystectomy (LAP)~~. The need for these surgeries is expected to rise in view of ageing populations. The exception is TAH, which is being replaced by minimally invasive laparoscopic hysterectomy (Gale et al. 2016). Studies have shown that a number of factors influence LOS following surgical procedures. These include patient characteristics - age, gender and body mass index for TKR (Jonas et al. 2013), TAH (Toma, Hopman & Gorwill 2004) and LAP (Ivatury, Louden & Schwesinger 2011). ~~Indeed~~Iindeed, the scrutiny on greater efficiency and financial sustainability has pushed for utilizing evidenced based tools such as enhanced recovery after surgery (ERAS), which influences surgical care time and complications (ERAS 2016). Studies have investigated the impact of implementing ERAS on LOS, which is reduced following implementation (Wijk et al. 2014) (Thiele et al. 2015, Keller et al. 2014, Miller et al. 2014, Aarts et al. 2012). However, ERAS' adaptation and implementation has been slow due to poor evidence from outcome data, difficulty bringing multidisciplinary groups together, resistance to change at the institutional level (Kehlet, Wilmore 2008), and little evidence outlining cost-effectiveness (Lee et al. 2014). So, while ERAS protocols address care pathways through a focus on clinical operative factors, other patient and health system factors are not directly considered which explains the lower stakeholder involvement and adoption. This research aims to fill this gap by considering criteria beyond the traditional medical ones. ~~With this~~This study ~~therefore, we~~ aims to develop a holistic model for deriving LOS, which incorporates multiple criteria – such as clinical medical, social, financial and risk and engages concerned stakeholders. Additionally, this study demonstrates ~~its~~ the application of multi-criteria decision-making in real life. ~~We will then apply an analytic tool to this model,~~ to scientifically assess the best LOS policy alternative for three surgical procedures in a public hospital in Malta through the use of actual patient outcome data and engagement of multidisciplinary stakeholders' (e.g. surgeon, patient or patients' relatives, hospital management and other medics) perspectives.

The remainder of the paper is organized as follows. Section 2 demonstrates in detail the methodology and the model for deriving LOS for specific intervention along with the application. Section 3 discusses the contributions of the proposed approach while Section 4 concludes the study.

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METHODOLOGY AND RESULTS

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Setting

The health system in Malta is based primarily on a publicly-funded national health system, which is supplemented by the private sector. In 2012, the national average LOS for all causes in acute hospitals was 5.3 days while the national bed occupancy rate was 83.2% (World Health Organization 2005). The public hospital in this study is a 250,000m^2 complex with 827 beds and 25 operating theatres.

The remainder of this section will outline the five steps to develop a holistic model for deriving the best policy alternative for patient LOS.

Step 1: Developing the decision model on LOS for specific interventions~~conceptual model~~

The conceptual model applied was developed through extensive literature review, as well as consultation with key stakeholders (e.g. surgeons and other medical doctors, nurses and allied professions, patient or patients' relatives, hospital management ~~and other medics~~) through focus groups, after which criteria and sub-criteria considered for analysis were mapped out. As described by Schorr (Schorr 2012) factors that influence LOS can be grouped into three broad categories - Patient, social and family environment, Clinical caregiver and Health care system (Table 1):

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Each focus group consisted of a mean of ~~9~~ nine health care and hospital management professionals. The participants, who were presented with information derived from the literature review, provided their feedback, leading to the final criteria and sub-criteria of the model (Figure 1). A hierarchical model was formulated with the goal being policy selection on LOS and the criteria that were considered being Medical, Financial, Social and Risk are considered as criteria. Type of surgical intervention, likely condition of patient post-surgery, and expected outcomes wereare identified as medical sub-criteria. The sub-criteria - cost / benefit, capital and operating cost are considered within financial criteria. Patient satisfaction, community care provision, and family support are identified as sub-criteria for social criteria, and risk criteria are covered through readmission chance, possible discomfort, and likelihood of adverse event.

INSERT FIGURE 1

LOS policy alternatives (policy A – stringent target, Policy B – Moderate target, Policy C – Lenient target) were then developed based on patient data of the hospital under study available from January to December 2011. A random sample of 360 patients – 120 patients per procedure - from the hospital's patient administration system was extracted. Of the 120 patients, who underwent a TKR, five files were not available. Of the 120 patients, who underwent LAP, 8 files were unavailable, 9 were incorrectly coded, 8 were converted to open cholecystectomy and 1 non-show patient. Of the 120 TAH patients, 4 files were unavailable. Therefore, the final sample was 325 patients (90.3%).

This patient data were analyzed to derive the current average LOS for each procedure (Figure 2):

INSERT FIGURE 2

Using these current ranges for the LOS for each surgery, three policy alternatives were outlined. Basing on the above displayed distributions, cutdistributions, cut off points for each LOS range were developed for each procedure under analysis outlining the policy alternatives from the patient data. The data for each procedure were split into three cut points, each containing 33% of the respective sample. These uniform cut-off points based on the data distribution then delineated the policy ranges for the LOS to be analysedanalyzed. This methodology was chosen since it could be applied uniformly across all three procedures. Furthermore, this method considered the entire LOS range including extremes, thus ensuring that the LOS policy alternatives reflected the true range of LOS's for each procedure. The policy alternatives are illustrated in Table 2.

INSERT TABLE 2

The analytical tool was selected to scientifically fit the three interventions being studied. The complexity of hospital LOS demanded that flexibility of the tool needed to address the multi-criteria hierarchical structure, while incorporating both quantitative and qualitative multi-stakeholder perspectives (Pauly 2011). With this in

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mind, we chose a multiple criteria decision-making method for model building and data analysis involving two procedures. The first is using the ~~we chose the~~ Analytical Hierarchical Process (AHP), a multiple criteria decision-making technique ~~-~~ developed by Saaty (Saaty 1994, Saaty 1977) for the verbal subjective judgements on prioritizing the four predictors of surgical LOS – medical, financial, social and risk. ~~-~~ The AHP has been extensively utilized in different fields and for various situations (Saaty, Sodenkamp 2008). The mathematical underpinning of the AHP has been described in ~~appendix A~~the Appendix. As shown by Saaty and Vargas (Saaty, Vargas 2006), the AHP can incorporate expert clinical judgment with statistical data so as to develop the best alternatives for decision-making. The steps for applying the AHP are as follows: d

- ~~D~~evelopment a hierarchical model with goal for decision-making, criteria and sub-criteria, and decision alternatives with the involvement of the concerned stakeholders; p
- ~~P~~air-wise comparison of criteria ~~and sub-criteria~~ using verbal scale as indicated in figure with the involvement of the concerned stakeholders to derive importance of criteria; ~~and sub-criteria~~d
- ~~D~~eriving the relative preference of the alternative decisions by comparing each alternative pair-wise; and ~~-~~s
- ~~S~~ynthesizing the results across the hierarchy to derive the overall ~~ranking~~priority vectors of the decision alternatives.

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The second procedure involved pairwise comparisons of the sub-criteria under each criterion in line with the concerned interventions – the objective data of which are obtained from the patients' files. In this part, we could not apply AHP as the sub-criteria were not scored through verbal judgements. Therefore, only pairwise comparisons of objective scores for the sub-criteria were employed (~~-~~Supplementary file ~~SHEET 1~~ provides details of the coding used for data collected for patients who underwent laparoscopic cholecystectomy as an example, together with the anonymized data set so as to provide visibility of computation of values for the sub-criteria).

The multi-criteria decision-making~~is~~ method structures problems in the form of a hierarchy, mainly goal, criteria, and alternatives (Bernasconi, Choirat & Seri 2010). By using pairwise comparisons, ratio scales are calculated, providing numeric scales. There are other methods (e.g. analytic network process, fuzzy theory, multiple attribute utility theory and value theory, and The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)) that could have been adopted. However, ~~the AHP~~this method seems to be the most appropriate one due to the characteristics of the criteria and decisions that are to be made, as well as the user friendliness of the method and easy to adopt with the existing practices. ~~The mathematical underpinning of the AHP has been described in appendix A. The steps for applying the AHP are as follows:~~

~~Development a hierarchical model with goal for decision-making, criteria and sub-criteria, and decision alternatives with the involvement of the concerned stakeholders~~

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~~Pair-wise comparison of criteria and sub-criteria using verbal scale as indicated in figure with the involvement of the concerned stakeholders to derive importance of criteria and sub-criteria~~

~~Deriving the relative preference of the alternative decisions by comparing each alternative pair-wise~~

~~Synthesizing the results across the hierarchy to derive the overall ranking of the decision alternatives~~

Step 2: Model application and determining importance of criteria

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The three surgical procedures considered are laparoscopic cholecystectomy (LAP), total knee replacement (TKR), and total abdominal hysterectomy (TAH)~~ and laparoscopic cholecystectomy (LAP)~~. Table 3 describes the three procedures and includes the number of procedures conducted within the hospital under study in 2011.

INSERT TABLE 3

In this step, pairwise comparison using verbal scale as per AHP method is used.

~~INSERT TABLE 4~~

~~INSERT TABLE 3~~

The higher order criteria outlined in the model – medical, financial, social and risk – are the common vectors and are applied to all policies. The sub-criteria are policy specific vectors and vary depending on the procedure. To develop a total policy rating for each alternative policy, ~~using the AHP,~~ the common and policy specific vectors were ~~calculated~~derived. The common criteria vectors were calculated using expert verbal judgment of preference ~~(tablesupplementary file, SHEETSheet 2, Step 1)~~ assigned by the members of the focus group for pair–wise comparison. The importance of criteria (policy vectors) as derived from the pair-wise comparison are ~~The focus groups assigned preference scores as follows (ranked from highest to lowest)~~ – Medical (~~9~~0.5330~~1~~), Risk (~~7~~0.2609~~1~~), Social (~~5~~0.1058) and Financial (~~4~~0.102~~1~~). ~~Similarly, t~~The importance of all the sub-criteria is derived through pair wise comparison (c.f. supplementary file~~, Sheet 1)(supplementary file, SHEET 2, Steps 2 and 3)using same verbal scale~~. Subsequently, preference of each alternative decision is derived through pair wise comparison with respect to each sub-~~criteria~~criterion. All the above pair wise comparisons matrixes are shown in the Appendix for the three interventions. Finally, the importance of all the criteria and sub-criteria is synthesized along with the preference of three alternatives with respect to each sub-criteria that results the overall ranking of the decision alternatives for three interventions ~~(table). For the policy specific vector scores, sub-criteria for each surgery were outlined and scores given based on the current sampled patient outcome data. Since no cost data were available, the policy specific financial scores were calculated based on the assumption that the longer the LOS, the higher the cost per patient. Therefore, for each policy alternative, a score was assigned based on the nine point verbal judgment scale used for the common criteria. The stringent policy~~

alternative was considered the highest scoring on the financial scale as it had the lowest LOS target and it was assigned a score of 9, the moderate policy alternative was assigned a score of 5 and the lenient score was assigned a score of 1.

These vectors, namely common medical vector (CMV), policy medical vector (PMV), common financial vector (CFV), policy financial vector (PFV), common social vector (CSV), policy social vector (PSV), common risk vector (CRV) and policy risk vector (PRV) compute into the policy rating score as follows (refer to appendix 1 for more details):

PR = CMV*(PMV) + CFV*(PFV) + CSV*(PSV) + CRV*(PRV)

After applying the conceptual model to each intervention- (as shown inc.f. sSupplementary fFile, SHEET sheet 23)using the AHP, the best policy alternatives for each procedure are outlined in Table 4. The policy with the highest ratio score is considered the best policy alternative.

INSERT TABLE 454

Step 3: Gathering data on each sub-criteriacriterion for specific policy and cComparing the best policy alternatives to present patient data

In this step, the sub-criteria based on coded objective data from the patients' files (c.f. supplementary file, sheet 1) were analyzed.

Laparoscopic Cholecystectomy

The current average LOS for LAP in the hospital under study is 2.2 days, which is within the best policy alternative of less than 3 days as derived from the applied model.

Total Knee Replacement

The current average LOS for TKR in the hospital under study is 6.61 days, which is above the best policy alternative of ≤ 4 days. Since the present average LOS is above the alternative, univariate analysis was conducted to assess possible differences between patients falling within the three policy alternatives. Mann Whitney U, Kruskall Wallis H and Spearman's Correlation tests were used (Table 5).

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The results show that those with a longer LOS were older ($p<0.05$) however were more independent ($p<0.01$) which may reflect broader social support needs of patients as this age, something which may impact upon recovery. This raises the issue that for the hospital to function effectively, it must be adequately supported by the entire health and social systems. Indeed, in areas such as acute rehabilitation, external services and social support are crucial to enable surgeons to adopt the appropriate LOS policy. Apart from this however, patients with longer LOS were similar to those with shorter LOS across various clinical and demographic characteristics.

In monetary terms, a shift of the average LOS to 4 days from 6.61days would equate to considerable yearly savings. The estimated cost per surgical bed night for Orthopedics in the hospital is €191.12 (TOM 2012). For 467 procedures in 2011 with an average number of bed nights per procedure at 6.61 days, the hospital dedicates on average 3086.87 bed days for TKRs. In monetary terms this would equal €589,963 spent annually on occupied bed days. Should the alternative best policy be affectively implemented, we can expect the total average number of bed days for TKRs to be 1868 equal to an annual cost of €357,012. This indicates an annual saving of €232,951 from LOS reduction in TKRs alone.

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Total Abdominal Hysterectomy:

The current average LOS for TAH in the hospital under study is 6.61 days, which is above the best policy alternative of less than or equal to 4 days. To investigate possible differences between patients falling within the three policy alternatives, univariate analysis was also conducted. Mann Whitney U, Kruskall Wallis H and Spearman's Correlation tests were used (Table 6).

INSERT TABLE 6~~7~~6

The results revealed that patients suffering from cancer had a longer LOS ($p<0.05$). While this is expected, this result raises the issue that management should support clinicians in one-to-one clinical decisions when treating patients with unique demands. When excluding patients who had cancer as an indication for surgery, there were no differences in patients' features across the three policy alternatives. Therefore, notwithstanding any patient specific clinical decisions, the best policy alternative is a benchmark that can be applied across patients undergoing a TAH.

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Similar to TKRs, a shift of the average LOS to 4 days from 6.11 days for TAH would equate to considerable yearly savings. For 480 procedures in 2011 with an average LOS of 6.11 days, the hospital dedicates on average 2932.8 bed days for TAHs. The estimated cost of a bed in gynecology is €179.10(TOM 2012). In monetary terms this would equal €525,265 spent annually on occupied bed days. Should the alternative best policy be affectively implemented to reduce the average LOS to a maximum of 4 days, we can expect the total average number of bed days for TKRs to be 1920 equal to an annual cost of €343,872. This indicates an annual saving of €181,393 from LOS reduction in TAH alone.

Step 4: Benchmarking policy alternatives against international standards

The maximum for the best policy alternative and present average LOS for each intervention were compared with international benchmarks (Figure 3).

INSERT FIGURE 3

The average LOS for LAP for the UK (NHS 2015) also fits within the best policy alternative range derived from the model and is similar to what is being experienced in Malta. For TKR and TAH, we found more comparative statistics for LOS. The average LOS for TKR for Finland, Canada and the United States (Cram et al. 2012) are within the best policy alternative range derived from the model. This is similar for TAH which compared well to the benchmarks for LOS for the UK (NHS 2015), Denmark (Lykke et al. 2013) and the United States (Warren et al. 2009). For both these procedures, the present patient data show that the average LOS in Malta is above the averages experienced in these countries. Comparing the derived alternatives from our model with international benchmarks suggests that the alternatives outlined in this study are realistic targets.

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Step 5: Actions for implementation of model

The ~~AHP~~multi-criteria decision-making -based framework for deriving LOS for specific interventions ~~is holistic methodology (Figure 4)~~ is a unique approach to deciding upon the best policy alternative for LOS within hospital because it incorporates evidence from the literature, as well as site-specific quantitative patient data and qualitative stakeholder's perspectives. Furthermore, it allows for an in-depth analysis of patient characteristics, an important factor to consider when the average LOS is outside the best policy range. This ensures a better understanding of any system-level deficiencies, which may need to be addressed before adopting the best policy alternative.

While the flexibility of the model allows for it to be adopted effectively in any setting and for any intervention, its implementation requires a number of things to be in place. Firstly, all stakeholders need to be onboard to contribute to the development of the criteria while also being amenable to implementing the policy alternative that the model derives. Secondly detailed patient data are important to allow for the quantitative and analytical component of the model to be applied within the setting being studied. Data are also important for economic assessment of the possible gains to be made by implementing the policy alternative.

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DISCUSSION:

Hospital LOS is an important measure of quality and efficiency within hospitals and recent emphasis has been put on reducing LOS across countries. Some health care settings have adopted surgical protocols such as ERAS with the aim of improving post-surgical outcomes. While such protocols show a measure of improvement in LOS, implementation and adaptation has been slow as focus still remains on clinical care factors. Without a comprehensive multi-criteria decision-making model that engages all stakeholders, ownership and adoption of policies and protocols may not be sustainable. A paradigm shift is therefore needed to ensure that decisions are made based on a strong evidence base; moving away from decisions that are arbitrarily taken by individual clinicians (Hollnagel, Braithwaite & Wears 2013). This study has developed and applied a holistic model to determine optimal LOS. It outlines four major criteria to consider when developing LOS benchmarks within hospitals – medical, social, financial and risk. The model shows how health managers and clinicians need to consider all four criteria when determining the best policy alternative to ensure a balance rather than a trade-off between health care quality, efficiency, costs and LOS. The application of the model through an objective analytical tool yielded three policy alternatives for the surgical procedures considered which compare well with the average LOS found at country level internationally. ~~This study has demonstrated how decisions in hospital management can benefit from scientifically based multi-criteria tools.~~

When considering the complexity of the health system and its impact on LOS, the most appropriate policy alternative would help achieve financial sustainability without compromising on other important healthcare outcomes. With the implementation of the highest rated policy alternative therefore; we can expect an increase in cost effectiveness, efficiency and a faster release in beds. When considering the two procedures, which demonstrated ~~a present~~the current average LOS above the best policy alternative, implementation of the policy alternative could lead to a considerable reduction in costs. The estimated annual savings would be that of €414,344 for the hospital from LOS reduction in TKR and TAH alone. If this is extrapolated to so many other procedures that are carried out in the hospital, the savings could potentially run into millions annually.

However, one must not forget that the hospital does not function in isolation and this study shows that it must be supported system-wide by both health and social policy sectors. For ~~example~~example, shorter length of stay may enhance the social burden and risk of inadequate support/care post-op in the community. Decisions about LOS should also include the unique demands of individual patients. While the methodology ensures that stakeholders' perspectives are considered, the judgment of the clinician with respect to specific individual patients' needs must always be taken into account. This study has shown that the current LOS for two out of the three procedures fall short of the best policy alternative and this may be indicative of pervasive contextual factors within the hospital system. However, when excluding these factors; the policy alternative outlined is generalizable across patients. A limitation of this study is the lack of patient level financial data, which would provide a richer analysis of the financial sub-criteria. On the other hand, a major strength is the large randomly-selected patient sample, as well as the application across three surgical procedures.

CONCLUSION

Multi-criteria decision-making tools enable management to optimize resource use, through the application of a scientific management technique with the involvement of all relevant stakeholders. The model developed and applied is flexible and can be adopted across different settings. It allows for the development of context specific criteria, ranked and scored based on stakeholder preferences and objective statistical data. Future studies can apply this method to other interventions across health care settings to demonstrate its applicability within the broader healthcare context.

Compliance with Ethical Standards:

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Conflict of Interest: Authors declare that they have no conflict of interest.

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

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