Simulation of "a week care unit" organization in an academic hospital

G. Sinnaeve [1], C. Beguin [2], P. Chevalier [3] and M. Philippe [4]

[1,3] Université Catholique de Louvain, Voie du Roman Pays, 34, L1.03.01 - B-1348
Louvain-la-Neuve, Belgium
[2,4] Cliniques universitaires Saint-Luc, Avenue Hippocrate 10 - 1200 Bruxelles, Belgium

E-mail: `gilles.sinnaeve@uclouvain.be`

E-mail: `claire.beguin@uclouvain.be`

E-mail: `philippe.chevalier@uclouvain.be`

E-mail: `marianne.philippe@uclouvain.be`

Abstract. Poor bed allocation to each specialty might lead to a surplus of available beds during weekends. The introduction of a "week unit" that is only available during working days may improve the efficiency of bed allocation by uniting the patient flow of two regular units, before converting the regular beds of one unit into week beds. In order to test the possible introduction of this system in three services of the Saint-Luc hospital, we created a simulation model that considers new allocation rules to direct the patients into the right unit.

1. Introduction
Historically, the organization of care units has always been based on a predetermined number of beds allocated to each medical specialty. This distribution method leads to an inefficient use of beds when considering patient flow. A surplus in the number of available beds during weekends is particularly common. A strategy that combines one regular hospitalization unit with one "week unit" that is only available during working days may improve the efficiency of bed allocation.

1.1. Different types of SSU
Short stay units (SSUs) take a variety of forms in the literature, depending on the author's definition. One generally accepted basic definition is suggested by Damiani [8]: "It is a type of admission that can provide targeted care for patients requiring brief hospitalization (< 5 days), as well as patients ready to be discharged as soon as their clinical condition is resolved. Usually, the SSU is open from Monday to Friday, 24 hours a day, and provides the same level of medical care as an ordinary ward". In this system, admissions and discharges are specifically timed, with, for example, opening days restricted to week days. Consequently, patient treatment slots are reserved for during the week. In contrast to Damiani, other authors have proposed alternative definitions based on location, access, and opening hours. The majority considers an SSU to be closely linked to the emergency department [1]. Its access can be restricted to an explicit list of pathologies, such as respiratory diseases [2, 3], or to thyroidectomy patients [4]. It can also be solely dedicated to patients in good enough condition to be likely to recover within a short

period of time, i.e., with a lower rate of complications [5, 6]. In addition, opening times may range from 5 to 7 days a week.

1.2. The week unit and its advantages

SSUs offer many advantages that have been widely documented in the literature. Firstly, the nursing staff has increased capacity to deal with rapid cases, depending on the SSU's specialization. Secondly, the entire team becomes more and more accustomed to the related administrative tasks. As a result of these two advantages, many authors [8] have observed a reduction in the average length of stay, without any side-effects. The quality of care provided has been shown to remain stable or improve, while the same number of patients still receive treatment during the week days. The hospital can also save on human cost during the weekends, when at least eight beds are converted into week beds [9]. Reviewing bed allocations for each medical and surgical specialty of a hospital could, however, prove a complex task [10]. An SSU could be introduced to compensate for poor bed utilization rates during the weekends that are the result of the current organization of the operating area.

1.3. Discrete event simulation

Discrete event simulation is becoming an increasingly popular tool in the healthcare field. It allows us to replicate a real-world system in order to virtually experiment with some changes. The consequences of the changes are gathered and analyzed before being implemented in a real setting [11]. The system's performance is evaluated on appraisal of how the selected performance indicators evolve when faced with modifications in some parameters. "What if" scenarios are developed and compared in order to determine an ad hoc solution based on the elements from the real system. For an overview of the potential applications of discrete event simulation (DES) in the healthcare sector, we refer to Jacobson [12]. The steps and skills required to build a valid simulation model were developed in full by Carson [13] and White in 2009 [14].

1.4. Contribution of the paper

In this paper, we will henceforth refer to a specific type of SSU that only concerns hospitalization units open 5 days a week. This so-called "week unit" implies uniting the patient flow of two regular units, before converting the regular beds of one unit into week beds. The bed allocation is then organized based on the estimated length of stay, with short-stay patients allocated to the week unit and long- or varying-stay patients to the regular unit. In cases where short-stay patients have to be admitted for a weekend, they are transferred to the regular unit. This definition is compatible with that developed by Renaut in 2009 [9]. To the best of our knowledge, the week unit system has never before been virtually tested.

We believe that our study could contribute by:

 (i) Further increasing the growing number of simulation applications in the healthcare field;

 (ii) Shedding light on the performance of a week unit;

(iii) Evaluating the impact of introducing a week unit at a university hospital.

2. Methods

Configuring a week unit consists of separating the patient flows based on new allocation rules. These rules are based on specific criteria designed to predict patient length of stay. In this way, patients from the gynecology, urology, and ophthalmology services are directed either to the week or regular unit. To select the best length of stay predictors, we needed to analyze and compare each criterion. To this end, we accumulated a database including all hospitalizations in 2011, with data on personal information and surgical operations. We could then use this historical data to build our simulation model, rendering it capable of conducting tests to compare how well

the two kinds of patients were separated. The preferred algorithm was one exhibiting the lowest number of inter- or extra-unit transfers and the most balanced utilization.

2.1. The Saint-Luc hospital and its services

Founded in 1976, Saint-Luc is an academic hospital in Brussels equipped with 979 beds. These beds are distributed across the 10 floors of the hospitalization tower. Each floor is composed of four units of care, with each unit offering approximately 30 beds. The beds are allocated to rooms that can either be private or double.

We tested the week unit concept in the following three services, spread over two parallel units: gynecology (U94), urology, and ophthalmology (U93). This particular hospital's structure highly favors inter-unit interaction due to the multiple access points linking the different units. These units were chosen for several reasons:

 (i) The similarities in the way patients are treated in the urologic and gynecologic services;

 (ii) The low proportion of emergency cases;

(iii) The large proportion of short-stay patients;

(iv) The current restricted opening times of the U94 (from Monday 7am to Saturday 12am).

2.2. Data collection

The dataset used is the outcome of merging operating databases with the RHM (*Résumé Hospitalier Minimum*, patient information that every Belgian hospital is legally required to submit to the government to qualify for funding). The Belgian financing system relies on rates fixed in advance for each APR DRG (All Patient Refined Diagnosis Related Groups). This classification system uses the previous system of DRGs (Diagnosis Related Groups), which are divided into four different SOIs (Severity Of Illness) [15]. This dataset contains different criteria that were selected and gathered for their ability to predict patient length of stay. Database refers mainly to personal data, specific stay (including DRG, SOI and hospital access) or performed surgical operations. We focused our interest on the data taken from 2011. According to key members of the Saint-Luc hospital team, 2011 presented no specifically unusual data and thus could be representative for an analysis of the three concerned services. Nevertheless, approximately 100 patients who had more complex records were excluded from this study.

2.3. Profile analysis

The database comprises approximately 3,089 stays, divided among three services. There were 1,379 in gynecology (44.64%), 1,070 in urology (34.64%), and 640 in ophthalmology (20.72%) in 2011. Table 1 reveals the most relevant figures of this 2011 sample profile analysis.

Table 1. Basic statistics for the most relevant criteria of the 3 services

Criteria	Gynecology	Urology	Ophthalmology
Proportion of emergency patients	7%	21%	8%
Proportion of weekend patients	25%	51%	45%
Average length of stay (days)	2.75	3.50	2.56
Proportion of stays < 2 nights	54%	51%	78%
Number of DRGs	11	18	8
1 DRG includes > 50% of the patients	DRG 513	None	DRG 71

Basic statistics and comparisons indicate that the DRGs represented the best length of stay predictors among the selected criteria. Nevertheless, their efficiency contrasted with the high number of DRGs per service (Table 1) and the length of stay variability within the groups. Introducing SOIs into the model reduced this variability. However, most of the pathologies treated in these services exhibited a low SOI of 1 or 2, rarely scoring higher.

Finding good predictors of length of stay is reputed to be a challenging task. Most researchers have attempted this for economic purposes [16]. Still, even if DRGs did not appear to be perfect indicators of length of stay, neither personal data nor information concerning potential operation offered better predictive power.

2.4. Model description

A model is an abstraction of a more complex phenomenon. It allows us to simplify the different elements in order to focus our interest on the interactions between selected elements. A model is created in order to simulate the behavior of a process [14]. The AnyLogic software was chosen for this purpose.

In our AnyLogic model, the sources input patients at a predefined rate. Once input, each entity continued through the intermediate stage where patients were assigned to their unit based on an allocation algorithm. This algorithm relied on the DRGs and the SOIs assigned to each patient, as well as their arrival day. One of the aims of this study consisted in selecting the allocation algorithm that would minimize the number of patient transfers while providing the best workload balance within the two units. It decided where to send the patients itself, whereas the actual separation occurred in the switch. If there were no beds available, a weekday patient would first be directed to the regular unit, while a regular patient would be ejected from the system. This model also predefined the processing time, i.e., the time a patient will stay in the unit of care.

The outcome measures chosen for evaluating the system's performance were:

- Utilization rate: the number of patients allocated to each unit ;
- Internal transfers, from the week unit to the regular one ;
- External transfers, from the regular unit to the outside world.

We also considered the case where the units were combined. This model allowed us to test the consequences of considering the bed capacity of the two units together. If some patients were unable to find a bed in this model then even the most perfect allocation algorithm would not be able to achieve a better result.

The hospital stay of each patient from the database was simulated based on the historical data from 2011. In total, 3,089 gynecology, urology, and ophthalmology patients were allocated to one of the 51 available beds of the units 93 and 94. There are two types of rooms, either single (called "private") or double patients. 22 rooms of these units are double patients, while 7 are private. Even if double patients rooms could be privatized, we considered this number of private rooms as fixed. This configuration implies to take into account the separation of men and women in double rooms. We exclude this constraint from the model. Indeed, gender separation should not have a critical impact on the results and can be performed easily during the validation step.

The simulation relies on historical data taken from 2011, for both arrivals and length of stay. Data are mostly reliable on the days of arrivals, but not necessarily on the hours of arrivals and departures, indicated by the nurses when they have free time. This is the reason why we allowed recourse actions to add some flexibility to the simulation.

These recourse actions are presented under "what if" scenarios, and concerned:

 (i) The closing time of the week unit;

 (ii) The maximum waiting time for a bed when a patient arrive in the system;

(iii) The time left after a stay at the week unit;

(iv) The number of beds available in the regular and week units.

The time left after a stay in the week unit indicates how relevant a transfer from the week unit to the regular one is. Some constraints that were neglected in the virtual model are going to be taken into account in the validation phase. Two extra months will be tested manually in order to confirm the results found in the virtual simulation. This step was required by the hospital staff prior to testing the model in a real context.

2.5. Software description

We used AnyLogic version 6.0 to model the week unit system. This software is widely used in the literature, offering an extensive range of applications. Brailsford *et al.* [24] used this software to build a model combining discrete event simulation (DES) and agent-based modeling (ABM).

3. Results

3.1. The "As-Is" Situation

We started by representing the 2011 unit organization. The patients were directed to their units depending on the service in charge, with gynecology patients directed to unit 94 (U94) and urology and ophthalmology patients to unit 93 (U93). At the time of writing, four beds were dedicated to urology patients in unit 94 due to the rising activity of this service. The U94 closing time typically fixed at Saturday 12pm. In this setting, an average of 10 transfers per month was necessary to sustain the activity.

Table 2. Results for the As-Is situation

Waiting Time (h)	Internal Transfers	External Transfers	U94 patients (%))
2	117	4	45.29

3.2. One pooled unit simulation

This scenario consisted in considering the two units as a pool of 51 beds. The objective was for both teams to be mixed and versatile enough to cope with the variety of diseases from the three services. The U94 closing time was here advanced to Friday 10pm. The operating area organization, as well as the doctor's schedule, remained unchanged. Depending on the simulation, switching to a week unit implied five external transfers, directly related to the early closure of the week unit. The low number of transfers proved the advantage of the week unit system: if the perfect criteria were found, this system could be sustainable for all units concerned.

3.3. What if scenarios with parameters modifications

We selected appropriate indicators that enabled the scenarios to be compared. As a reminder, the routing algorithm was chosen for its ability to direct patients into their respective units while minimizing the number of transfers (internal or external) and providing the best workload balance within the two units. By gathering opinions from the hospital experts, we should be able to find the scenario that best represents their constrained system.

The results derived from the considered scenarios are summarized on table 3 below:

Table 3. Results for the different scenarios

Scenarios	Attempt	1	2	3	4	5	6
Parameters	Closing time (h)	20	21	22	20	20	20
	Time left (h)	12	12	12	12	12	15
	Waiting Time (h)	2	2	2	2	3	2
	Bed capacity	51	51	51	50	51	51
Results	Internal transfers	166	163	160	185	165	142
	External transfers	8	8	8	17	8	6
	Week patients (%)	50.31	50.28	50.31	51.25	50.44	50.28

The first three simulations analyzed the impact of closing the unit 1 or 2 hours later. All other things being equal, this had a limited impact on the number of transfers (internal or external) as well as the workload, measured based on the proportion of patients treated in the week unit. The maximum waiting time allowed for patients to obtain a free bed also has a limited impact. When this time was increased to 3 hours, only one transfer was saved compared to the first scenario, used as a baseline scenario. The parameters that most strongly influenced the indicators were the number of beds and time left for recovery after being transferred.

4. Validation

4.1. Physical validation

Physical validation consists in using a manual model, *i.e.*, post it notes. The relevant information for each patient is recorded on the note, such as identification number, arrival day and time, departure day and time, room, DRG, and service. Physical validation presents several advantages:

 (i) Increasing the persuasive power of the model;

(ii) Integrating constraints that are hard to simulate virtually;

(iii) Validating the results.

The health care teams called for a physical validation for two specific months. September 2013 and March 2014 were thus selected for their representative quality and higher number of patients, with 260 and 296 patients respectively.

September 2013 : The system of constraints for this physical simulation has been designed in collaboration with the medical staff. Firstly, doctors wanted to include the type of room (double or private) as a key factor for planning bed allocation. Room type is important to doctors for financial reasons, while patients care about their comfort and privacy. Assigning a double patients room for treating a single patient is now the prior bed allocation rule. Besides, gender separation can now be taken into account. Secondly, the doctors requested the addition of an extra constraint: gynecology and urology patients are not allowed to share a double patients room.

March 2014 : This simulation applied the same constraints as that of September 2013, except for the gynecology and urology room separation. The type of room remained the primary focus, followed by the allocation algorithm and gender room separation rule.

Table 4. Results for the different scenarios

Scenario	Attempt	September 2013	March 2014
Parameters	Closing time (h)	20	20
	Waiting Time (h)	2	2
	Bed capacity	51	51
Results	Internal transfers	7	12
	External transfers	0	3

Flexible bed allocation helps to increase private bed availability. However, when the number of privatized double rooms exceeded a limit on busier days, this was shown to lead to external transfers. This is why three patients were subjected to external transfers in March 2014, in addition to the nine internal ones. These results confirmed those from the simulations. With an average of 13 patients transferred every month over one year, the allocation algorithm based on DRGs provided a fair representation of what could happen in reality. As shown in Appendix B, the number of patients transferred may vary from 4 to 24 transfers per month, with no specific correlation to the number of patient arrivals.

4.2. Field implementation
The health care team reaction of both units was mixed at the announcement of the experiment, initially planned for 6 weeks. This is not surprising considering the size of these teams (about 20 nursing staff members and 10 doctors). After a clear definition of the concept and multiple validations using historical data, it was decided to advance the closing time without changing the allocation system. Ophthalmology and urology patients are still directed to unit 93 while gynecology patients are taken care of at unit 94. The priority is set to avoid any useless transfer. Slowly, doctors are collaborating by adapting the operating area schedule to improve the new discharge policy. Others are making arrangements to transfer their patients into what they consider to be a more suitable unit.

In order to slowly switch to a week unit system, the following steps are advised:

 (i) Standardize the processes;

 (ii) Improve the collaboration between nursing staff members;

(iii) Anticipating weekly flows variations;

(iv) Investigate on more apt predictors of the length of stay;

 (v) Train a single bed allocation manager to coordinate the three services.

The following conclusions may be drawn from the outcome of the 6-week test. Firstly, the two nursing staff teams found a lot of common ground in terms of their working methods. The test also highlighted the need for standardization, especially in terms of administrative processes. Secondly, nurses and bed allocation manager were found to start organizing meetings to plan long stays and forecasted transfers in the clear goal to avoid any useless or damaging transfers. The test revealed that four transfers a week seemed a reasonable workload for the staff.

Finally, Saint-Luc hospital should greatly focus on its communication strategies. The units involved in the test received poor institutional communication about the new system in place, leading to misunderstandings and pressure on both staff and patients. The hospital management decided to extend the test period in order to give enough time to the nursing staff members to get used to this new configuration.

5. Discussion

5.1. Week unit efficiency

We selected the scenario of 51 beds and 12 hours of stay for transferred patients, with a total number of transfers per month approaching approximately 13. The number of transfers, calculated using an allocation algorithm, were compensated by the economic benefits to be gained. Firstly, the increase in the utilization rate, which is difficult to translate into funding, and secondly, the savings made in terms of working time, estimated at 1 ETP per year. According to a similar study in France, savings can be made even after converting just 8 beds into week unit beds [9]. A staff specialized in dealing with short stays could also potentially aid in speeding up the recovery process, reducing the length of stay of week unit patients with no additional risks.

Other strategies could be put into practice in order to improve the efficiency of the week unit. Could doctors organize a gathering to evaluate the patient health status to avoid any useless transfer on Friday afternoon? Switching to a week unit system could also offer a good opportunity to revise current planning practices. Since a unit has to treat the same amount of patients in a shorter time, standardizing and reserving slots for both consultations and operations should enable staff to treat patients without damaging the level of care provided [9]. Schedule reorganization could be combined with a coherent discharge policy in order to reduce bed utilization rate variations [22]. It should not be forgotten that these results were found to induce minimal disturbance to the ward organization and quality of given care.

The model appeared to provide plausible results. We can thus conclude that the week unit system can reasonably be applied in the field.

5.2. Data availability

We observed that the workload was well balanced, with over 50% of patients directed to the week unit, implying an average of 13 transfers per month. This performance was achieved with the DRG system, mainly designed for economic purposes. Theoretically, a better allocation would lead to better performance. Saint-Luc hospital could either use its own internal nomenclature or the medical expertise of the doctors during consultations in order to better predict the length of stay. If this indicator were reviewed periodically, it could improve the predictive accuracy of the model.

5.3. Model

Length of stay and arrivals are both influenced by a large number of parameters that might be correlated, such as bed utilization rate, doctor's availability, season's of the year, DRGs, limited capacity of the Operating Area, etc.

In his attempt to simulate arrival rates, Harrison [18] observed that a subtle seasonal effect could have a significant impact on the bed occupancy rate. However, it is hardly noticeable on the plot of the cumulative arrivals over time (see Figure A). The seasonal effect, combined with LoS variations, implies a variation in the number of monthly transfers, as shown in Appendix C. Here we can see that a high number of monthly transfers did not necessarily correlate to arrival peaks. The plot on Appendix A clearly shows the length of stay variation following the day of arrival for all three specialties combined. By inputting the actual operational data

directly into the system, we were able to avoid making assumptions on the arrival distributions for both emergency and planned arrivals. Poisson distribution, widely used within the literature to simulate arrival rates, corresponded to our data according to classic χ^2 tests conducted in previous studies on the subject [19].

Furthermore, the use of historical data seemed to provide a solid foundation to this simulation, considering the unclear shapes of the length of stay distributions by DRG. The most popular distributions chosen were the LogNormal, Beta, and Exponential distributions. Some authors have proven the superiority of the LogNormal distribution in the context of LoS modeling [20].

A more accurate modelling would imply a much higher cost in data requirement. With the historical data from 2011 only, we succeeded in showing what would happen in 2011 if this system was put into practice. This simulation results from the trade-off between complexity and

5.4. Bed utilization rate
One of the primary objectives to achieve in order to balance the workload was to improve bed utilization rates. We computed the cumulative length of stay of the three services, giving 9,184 hospitalized days in total. With a unit being open approximately 48 weeks per year, we roughly estimated the total opening days for both units at 15,086, prior to introducing the week unit, and 14,186 after. This led to a 4% increase in the average bed utilization rate (from 61 to 65%). Managing the same number of patients a year in 5 days instead of 6 may also raise questions concerning the adequacy of planning organization and activity. Once a stable bed utilization rate is achieved, the staff could use it to better manage the unit.

5.5. Resistance to change
So far, the week unit has only partially been implemented on the field. The service based allocation rule is still effective, nurses only try to decrease the number of transfers while closing their unit one day earlier. This current organization implies an unbalanced workload, leading to possible dissatisfaction. So far, we noticed a poor activity level at unit 94 starting from Friday afternoon. Facing a huge resistance to change from the nursing staff members, the full project still need to be broken down into small steps and require long term assistance in order to be fully effective.

6. Limitation
6.1. Whole-hospital model
Modelling an entire hospital is difficult and costly. According to Cochran in 2006, few are the articles that use Discrete Event Simulation in order to study all hospital interactions. "Most models do not explicitly consider the interactions between different hospital units" [10]. Nevertheless, this model might be adapted individually to see the impact of the week unit system in other units. We might consider modelling units that seem appropriate for week units, and then linking them to take in charge the external transfers. For examples of whole hospital modelling, please refer to Demeester [23] and Schmidt [21], who are both using an affinity matrix to assign patients into wards but differ by their way of handling the patient's length of stay. Closing one unit during the weekends would add complexity to their model but seems reallisticaly feasible.
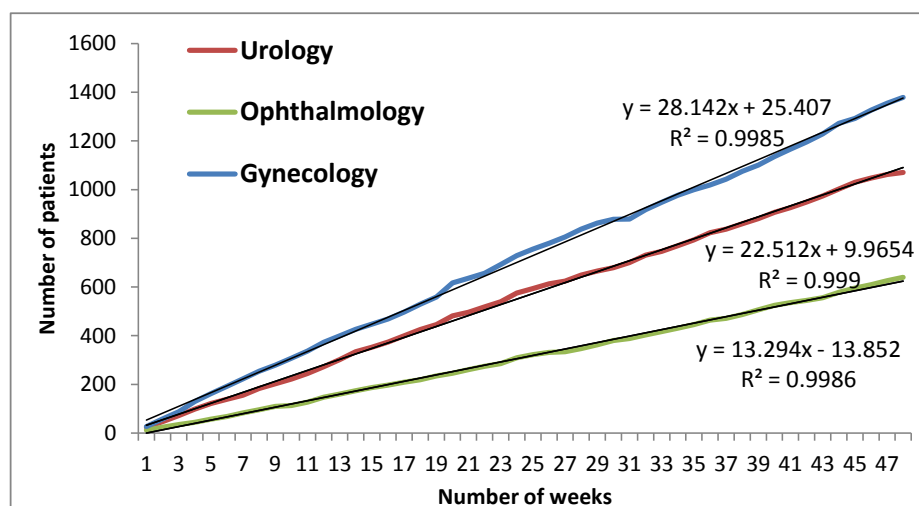
6.2. Software
AnyLogic is used for its capacity to handle complex interactions between elements. The more elements added to the model, the harder it becomes to add constraints reflecting reality. Like other modelers [24], we experienced limitations in the software beyond its basic functions. Java coding skills were required to overcome this problem. For example, two loops were necessary to limit the length of stay of the week patients following their entry day and time, since they were not allowed to stay in the week unit after Friday 8pm. Nevertheless, this software proved a suitable choice for dealing with a model of this size and level of complexity. For further information about package comparisons with other commercial software available on the market, please refer to [25].
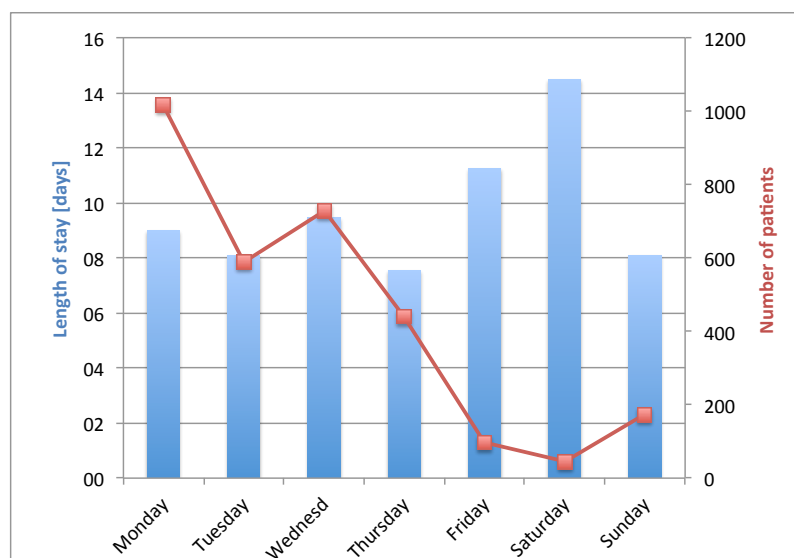
7. Conclusion

This study demonstrates the feasibility of gathering two units into a larger pool, allowing the "week unit" to close during weekends. The optimization of bed allocation paves the way for developing new perspectives in terms of care unit management.
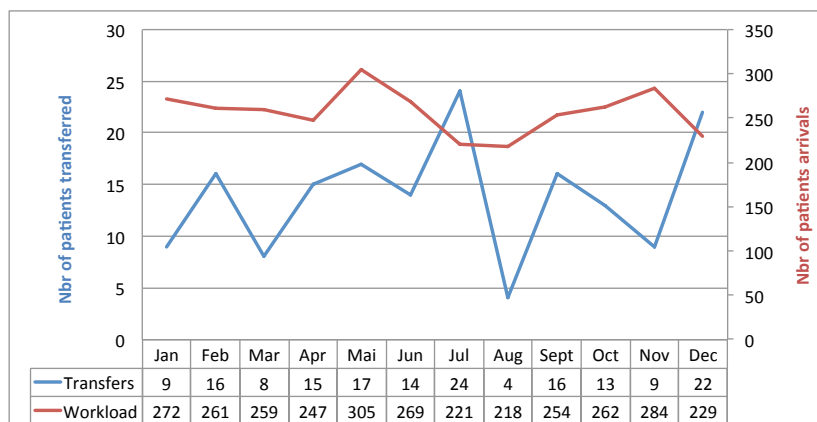
Appendix A.

Figure A. Cumulative arrival rate over time by service

Appendix B.

Figure B. Length of stay and patients arrival variations by day of the week

Appendix C.

	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Transfers	9	16	8	15	17	14	24	4	16	13	9	22
Workload	272	261	259	247	305	269	221	218	254	262	284	229

Figure C. Transfers and arrivals by month of the year

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