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PERFORMANCE EVALUATION OF AN INTEGRATED CARE FOR GERIATRIC DEPARTMENTS USING DISCRETE-EVENT SIMULATION

Thomas Franck
Vincent Augusto
Xiaolan Xie

UMR CNRS 6158 LIMOS
MINES Saint-Etienne
158 Cours Fauriel
42023 Saint-Étienne cedex 2, FRANCE

Regis Gonthier
Emilie Achour

CHU de Saint-Etienne
Hôpital la Charité
44 Rue Pointe Cadet
42023 Saint-Étienne, FRANCE

ABSTRACT

The increasing number of geriatric patients is one of the most important problems for the next years. This kind of patients is often dependent and does not tolerate environment changes so that hospitalization can strongly deteriorate the elderly health state. This paper focuses on two services of the geriatric services: the Short Stay (Acute Care) and Rehabilitative Care (to prepare the return at home). We use Discrete Event Simulation to compare two different configurations (integrated care vs separated) based on two French hospitals case studies. In the integrated configuration both services are located in the same department and in the separated configuration services are independent. We measure the impact of these organizations on the occupancy, admissions, waiting and the total length of stay. We also study the economic impact based on the French funding system taking into account the Diagnosis Related Group of the patient.

1 INTRODUCTION

1.1 Context

The French Institute Of Statistics (INSEE) predicts that the number of dependent elderly in France will be multiplied by two between 2010 and 2060 to reach 2,300,000 people (Charpin and Tlili 2011). The problem of elderly and health-care will be one of the most important issues for the next years. This type of patient needs a particular attention due to frailty and polypathology. Indeed, most of them have several illnesses which can be somatic or cognitive. In addition they have difficulties with environment changes which can aggravate the patient health state if the length of stay (LOS) is too long. Taking into account these last characteristics, the elderly pathway is complex and needs to be optimized. A patient pathway is a sequence of health and social services received by a patient.

In this study, we focus on the elderly pathway throughout the geriatric hospital, composed of two departments called “Short Stay” and “Rehabilitative Care”. The Short Stay (approximately 11 days LOS) is a service which concerns acute care. It means that patients have a unstable health conditions and can have difficulty tolerating the hospitalization (Gonthier et al. 2003). A large proportion of patients (approximately 50%) needs to be transferred to the Rehabilitative Care unit (approximately 15 days LOS). The goal of this department is to prepare the patient for discharge and return home (e.g. personal home, nursing home…) and to minimize the impact of the hospitalization.

Integrated care (collaboration between actors for the continuity of care) for the global pathway of patients is a promising approach (Somme et al. 2014) although no application to geriatric services has been studied in the literature to the best of our knowledge. The PRISMA project in Quebec (Canada) promotes health-care services integration through collaboration in the community with good results (Hébert et al. 2013). In France, the hospital funding system does not promote services integration because Short Stay and Rehabilitative Care are financed in two different ways.

These two departments have different aims but are complementary. An interesting question is to know if integration is beneficial for the patient and the functioning of the hospital. In this case, integration means that Short Stay and Rehabilitative Care are merged into one department. In this configuration, the patient keeps the same bed with the same staff (doctors, nurses…). Such approach is motivated by the fact that elderly have difficulty tolerating environment changes (Gonthier et al. 2003). With integrated care patients who need Rehabilitative Care have a more coherent pathway (less environment changes) .

1.2 Literature review

Although a lot of studies use modelling and simulation for performance evaluation of health-care systems or optimization of systems efficiency (Bhattacharjee and Ray 2014), few studies are focused on bed occupancy and/or geriatric services optimization. Taylor et al. (2000) used a 6 compartment Markovian model to predict the pathway of patients and help geriatricians to estimate beds requirements. Three compartments were services in the hospital (Acute, Rehabilitative, and Long Stay), two compartments represented community (Home and Nursing Home) and the last one was Death. Chaussalet et al. (2006) modeled these three hospital services with a closed queuing network and observed the impact of changing parameters like service rate per bed on the system and the number of bed, transition between services and discharge rate. This model have been previously studied by El-Darzi et al. (1998) using simulation. They measured the impact of a bad sizing which creates queues between services. Queuing theory was used by Gorunescu et al. (2002) to study the correlation between number of beds, number of patients turned away, bed occupancy and cost. The authors found that increasing the number of beds allows to decrease the number of patients turned away, but also deteriorates bed occupancy rate. A similar problem was tackled by Pehlivan et al. (2014), where queuing theory was used to optimize the resources of a perinatal network taking into account costs and patient rejection. Belciug and Gorunescu (2015) improved this study with a Genetic Algorithm mixed with queuing theory where the chromosome is the number of allocated beds, the arrival rate and the length of stay. The fitness function minimizes the cost of the hospitalization. De Bruin et al. (2009) used an Erlang loss model to dimension hospital wards with different specialities and found that big services decrease the amount of refused admission and increase the occupation rate. These results have been previously found by De Bruin et al. (2007) who studied the relation between two services (First Cardiac Aid and Coronary Care Unit) with a queuing theory and a two dimensional Markov process. The aim was to determine the good number of bed in each service to let the blocking around 5%. Katsaliaki et al. (2005) used a Discrete Event Simulation to test different services called “Intermediate Care” between the Acute Care and the Long Stay. These services included “Rehabilitation Care”. A lot of similar cases are mentioned by Vanberkel et al. (2009).

Economic analysis has been considered in some articles since health system costs compression is a crucial objective. Barton et al. (2010) measured the savings when the queue between Hospital and Private Nursing Home is reduced. They estimated a daily cost for acute care (£164.80) and for rehabilitative care (£114.80); these costs were based on the work of Saka et al. (2009). Gorunescu et al. (2002) and Belciug and Gorunescu (2015) used daily cost of £168 (£50 for the bed and £118 for the treatment), then a penalty which considers daily cost, LOS and a coefficient of 25%. Finally, Diagnosis Related Groups were used by Prodel et al. (2014) to estimate the economic viability of a hospital by considering emergency admissions.

1.3 Scientific contribution

In this paper, we propose an innovative approach to evaluate the benefits of integrated care for the elderly during their stay in the hospital. Using the same approach, we also propose a design of experiments to determine the optimal number of beds in each unit (Short Stay and Rehabilitative Care). Finally we propose a cost evaluation of these options. A daily cost for patients in the service was proposed in (Gorunescu et al. 2002) and (Belciug and Gorunescu 2015), but the authors did not take into account the variety of illnesses between patients. We use Diagnosis Related Groups (DRG) to have realistic results and conclude on the economic viability of the geriatric service.

To illustrate the methodology, we propose two configurations related to two hospitals (case studies): the University Hospital of Saint-Etienne (integrated) and the University Hospital of Clermont-Ferrand (separated). Performances of both systems will be evaluated using discrete-event simulation through various scenarios.

The paper is organized as follows. A formal description of the system using Petri nets is proposed in Section 2. Simulation model and scenarios are described in Section 3. Results are summarized and discussed in Sections 4 and 5. Finally, conclusions and perspectives are given in Section 6.

2 SYSTEM DESCRIPTION

As the study is based on the Saint-Etienne hospital situation, the following existing departments are considered in this study:

1. Short Stay (SS): department dedicated to acute care, the patient health status is generally unstable with comorbidity. The allocation of resources to the department is based on an activity payment rate (T2A, *Tarification à l'Activité* in French), which means that for each patient stay the hospital receives an amount of money depending on his/her pathology.
2. Rehabilitative Care (RC): department dedicated to the preparation of the patient to recover his/her autonomy while minimizing the effects of hospitalization. Generally, the patient comes from the Short Stay. It is financed by an annual amount allocated to the hospital every year. A part is paid by the patient and his/her social insurance.

2.1 Integrated and separated configurations

In the integrated configuration (Scenario 1) the Short Stay service and the Rehabilitative Care service are both in the same department. It means that the patient is not moved from one service to another during his/her stay. Figure 1 presents the Petri net modelling of the patient pathway in that case and Table 1 summarizes the principal transitions and places. Transitions model tasks or activities, places model waiting area or resource pools.

Firstly the patient in place p1 waits for an available bed (p6) in the SS/RC service. Then transition t2 is fired (the step is completed or the task is performed) and the patient arrives in the SS. After his/her stay, a meeting (t3) occurs between the doctor, the social assistant and the family to decide the future destination of the patient. He/she can leave the system (t7) if he/she is able to go back home or to a nursing home, or in the worst case, he/she can die. Another possibility is to go to the RC service by firing transition t4. If the patient is sent to RC, the bed is kept until the firing of t6 (end of stay). Other patients can integrate RC directly from outside of the hospital (personal home or nursing home) by firing transition t9.

In the separated configuration (Scenario 2), the difference with integrated configuration is the change of bed, staff and sometimes ward between the SS and RC department. In the Petri net proposed in Figure 2, it means that the patient leaves his/her SS bed and gets an available RC bed (p8) in t4.

2.2 Special features of the Saint-Etienne and Clermont-Ferrand situation

In the Saint-Etienne Hospital, each service (RC and SS) is separated into two (RC1/RC2 and SS1/SS2) in two different locations separated by 3.3 kilometers (RC1+SS1 in one building, RC2+SS2 in the other one). As there is no difference between each service (RC1+SS1 and RC2+SS2), we will consider each service as a whole (RCtotal + SStotal). There is a theoretical number of beds: 60 for the SS and 44 for the RC although integration makes this system flexible; hence we will consider only the total number of beds.

In the Clermont-Ferrand hospital the SS and the RC are separated and are also located in two different wards separated by 10 kilometers (RC in one building, SS in the other one). In addition, the RC department is not dedicated to geriatric patients and also accepts younger patients requiring rehabilitative care who come from other departments of the hospital. Taking this into account, the SS has 75 beds and the RC has 20 for elderly (56 in total). If the patient needs rehabilitative care when no bed is available in the hospital, the doctors need to find another hospital close to Clermont-Ferrand; otherwise the patient waits in SS.

The Saint-Etienne Hospital case is modelled using the integrated configuration presented in scenario 1, whereas the Clermont-Ferrand Hospital case is modelled using the separated configuration presented in scenario 2.

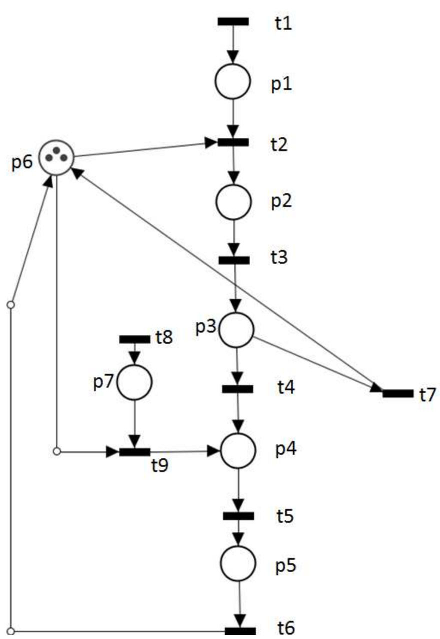

Figure 1 : Integrated configuration.

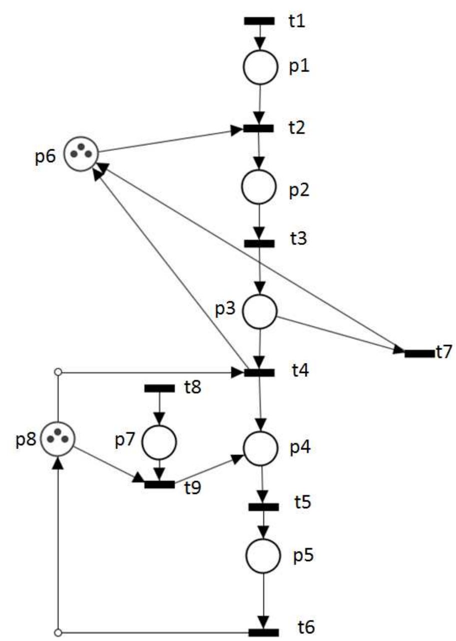

Figure 2: Separated configuration.

Table 1: Description of transitions and places.

Transitions	Description	Transitions and places	Description
t1	Arrival from home to SS	t8	Arrival from home to RC
t2	Accepted in SS	t9	Accepted in RC from home
t3	Meeting with doctors and family after SS	p2	Short Stay
t4	Accepted in RC	p4	Rehabilitative Care
t5	Meeting with doctors and family after RC	p6	SS beds
t6	End of hospitalization after RC	p8	RC beds
t7	End of hospitalization after SS		

3 SIMULATION MODEL

3.1 Data collection, distributions and model validation

All the data used for this model come from the geriatric department of the Saint-Etienne hospital. We have taken into account patients who have been hospitalized in the Short Stay, Rehabilitative Care and Palliative Care during the year 2014. Data collection includes arrival date, initial situation, pathway in the hospital and length of stay in services for each patient. We also know personal information such as age, sex, death during the hospitalization and DRG. All these data are anonymous to respect the confidentiality required in the French law.

In our case, we need to determine two types of probability laws: the arrival distribution and the length of stay. Most of studies use a Poisson distribution to model the arrivals in the system; as a matter of fact, collected data fit an exponential distribution. To determine the LOS in a geriatric hospital, McClean and Millard (1993) found that a mixed lognormal and exponential distribution fit better than an exponential distribution. In stroke unit, (Barton et al. 2010) created patient groups with a survival analysis and used a COXIAN distribution for the LOS. Groups have also been established by Rashwan et al. (2013) taking into account differences between frail and non-frail elderly. For this study, the DRG is used to model groups.

We used ROCKWELL ARENA 14.50 to simulate the model and the Input Analyzer to find the best distributions of patient arrivals, length of stay and probability of transfer between the different services. Table 2 summarizes the fitted distributions for each random element of the model. SS arrivals fit a Poisson distribution. Arrivals in RC are rare (1 during 2014). We used a constant distribution with 1 arrival every 100 days to model this.

Table 2: Distributions used in the model.

Parameters	Distribution
Patient arrivals directly in SS	POIS(4.59) per days
Patient arrivals directly in RC	EXPO(100) days
SS LOS	NORM(11.4,6.15) days
RC LOS	0.5 + GAMM(11.4, 1.29) days
Proportion of SS to RC	52.00%

To validate the model we injected the real instance from the data collection and we compared the data with the results of the integrated simulation model. These results are shown in Table 3. A 95% confidence interval is used to calculate the error on each result. If the observed value (reality) is between these two bounds, we consider the model validated. Two variables are out of bounds, the first one is the number of patients who arrived directly in RC. As we said previously, we have increased this value voluntarily, and as the value is very small, this is not significant. The second one is the RC LOS whose its value is 0.046 higher than the upper bound. We consider this variable validated because of the small amount of the gap between observed and simulated (the upper bound).

Table 3: Model validation.

Variables	**Observed**	**Simulated**	**Half Width**	**Lower Bound**	**Upper Bound**
Number of arrivals directly in SS	1676	1687.55	23	1664.55	1710.55
Number of arrivals directly in RC	1	4	-	-	-
Average los in SS	11,37	11,451	0,0761	11,3749	11,5271
Average los in RC	15,235	14.909	0,282	14,627	15,191
Number transferred from SS to RC	855	854.65	15.1	839.55	869.75

3.2 Scenarios and indicators

Simulation scenarios are proposed to test different configurations: integrated and separated as shown in Table 4. We also test various bed capacities through a design of experiment to find the optimal balance between SS and RC. The constraint is to keep the same number of beds because in the French regulation, it is impossible to increase the capacity according to the policy which consists in reducing cost. Based on the theoretical number of beds of Saint-Etienne (60 SS and 44 RC) we will increase SS beds and increase RC beds.

Table 4: Number of beds in each scenario.

Scenarios	Int	Sep1	Sep2	Sep3	Sep4	Sep5	Sep6	Sep7	Sep8	Sep9
SS number of beds	104	40	45	50	55	60	65	70	75	80
RC number of beds		64	59	54	49	44	39	34	29	24

The data collection is based on the patients admitted in SS. It does not represent the true arrival rate because for some patients, admission in SS has been refused. To make this model more realistic we will increase arrival distribution in the SS (Poisson distribution with mean 5.49) and we will measure the number of patients admitted in the SS service.

We will also use different indicators: number of patients refused in SS, occupancy of the services, total LOS, number of patient who have to wait between SS and RC, and transfers times between SS and RC. Patients are refused when the SS is full and cannot admits new patients, this indicator is more realistic than a waiting queue because when a patient has an acute problem, he cannot wait an available bed. The occupancy is an important indicator because if a bed is empty, the hospital does not get a refund and loses money. With the separated configuration, it is possible that the RC service would be full, in this case patients need to wait an available bed and stay in the SS; such indicator is also recorded. We consider only patients who wait a half day or more. The total LOS concerns only patients who needed SS and RC and is calculated in the following way:

$$\text{Total LOS} = \text{SS LOS} + \text{RC LOS} + \text{Waiting time}$$

4 RESULTS

4.1 Occupancy, admission, LOS, waiting and variability.

The simulation has been performed with 20 replications for each scenario. The length of replication is 415 days with a warm-up period of 50 days. In the following figures, integrated scenarios are denoted “Int” and separated scenarios “Sep” with the number of beds for each service. For example, “Sep 60/44” means a separated scenario with 60 SS beds and 44 RC beds. For each figure, integrated configuration (current state) is highlighted by a blue square.

Figure 3 presents occupancy rates of both services which is considered good when comprised between 0.9 and 1. The integrated scenario has a good occupancy (0.938). The separated scenario has good results too when the number of beds in SS is bigger than in RC. The occupancy is close to 1 because the RC has not enough beds to satisfy the demand. When the RC number of beds increases (and the SS number of beds decreases), SS occupancy rate stays close to 1 but RC rate decreases until 0.424 (Sep 40/64). In this case there are not enough beds in SS to admit more patients and the RC is oversized.

These conclusions are emphasized by the study of admitted and refused patients. Figure 4 shows that integrated scenario admits more patients than the separated for all ratios of beds. The number of rejected patients is correlated to the number of admitted patient. When a scenario admits less patients, it rejects more. Nevertheless the number of rejected patients depends on the new distribution arrival (POIS(5.49)) and cannot be considered as the real amount. The 60/44 ratio is the most adapted to satisfy the demand in the separated configuration. The integrated scenario is the most adapted because of its flexibility; in the separated scenario, if the SS is full it is impossible to admit more patient even if RC beds are still available.

Scenario (Sep 80/24) gives the worst results for admitted and refused patients. In this case, the RC service is undersized so a queue is created between SS and RC and patients stays in SS even if a transfer is required.

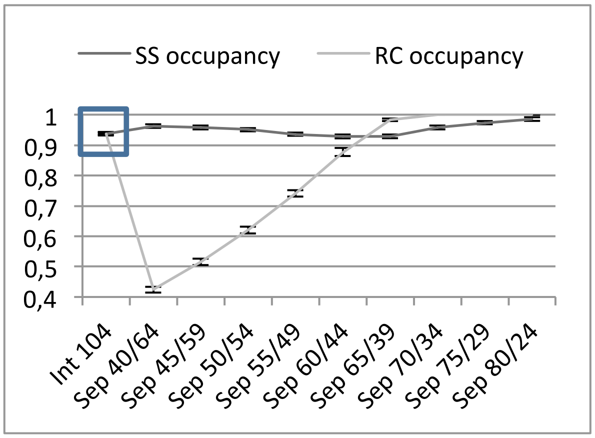

Figure 3: SS and RC occupancy.

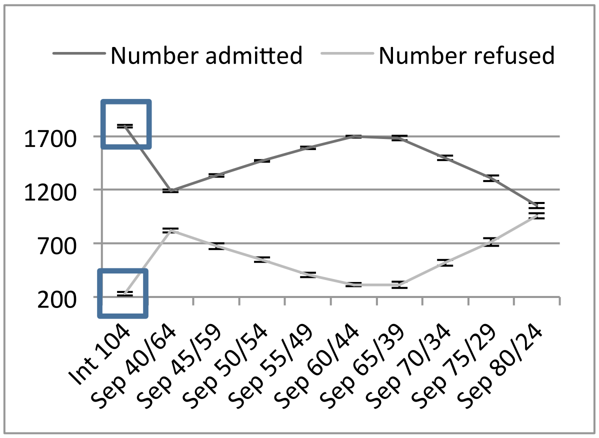

Figure 4: Number of admitted/refused patients.

Figure 5 presents the average number of waiting patients for each scenario. Scenario (Sep 80/24) is not the worst for that performance indicator because fewer patients have been admitted in the hospital, so fewer patients have required RC transfer. When there are more RC beds than SS beds, no patient is waiting between both services because RC is not full (Figure 3).

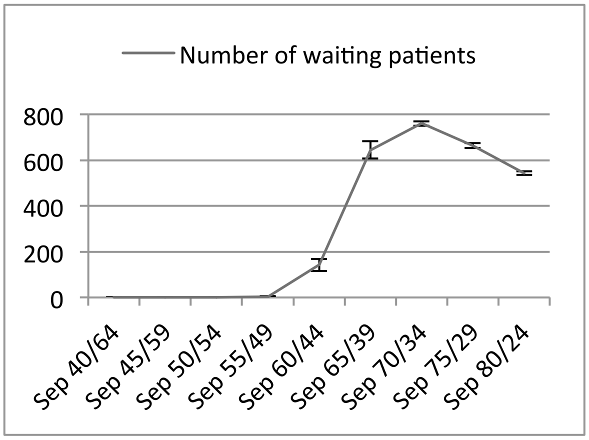

Figure 5: Number of waiting patients.

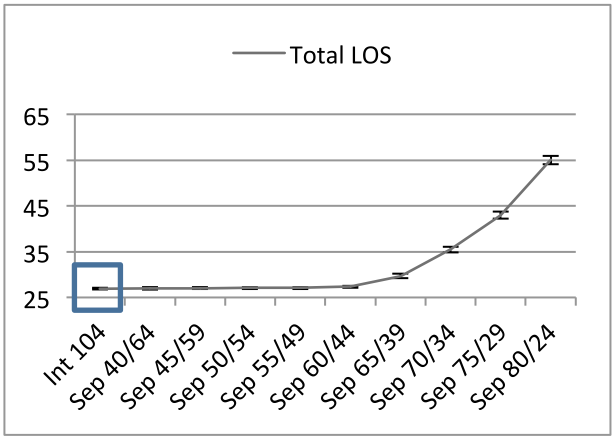

Figure 6: Total LOS.

The average total LOS (Figure 6) is the sum of SS LOS, RC LOS, and WAITING TIME of patient who have a stay in both SS and RC services. The difference between results is the waiting time generated for each scenario. Integrated scenario is the best (no waiting time) and Sep 80/24 the worst. When the number of beds is big in RC there is no waiting time because patients do not wait as shown in Figure 5.

The integrated scenario is the best for all performance indicators because of its flexibility; the drawback of such organization may appear if the variability of the number of beds at a given time is too high. French health authorities want to control spending of hospitals and both services are financed in two different ways (fee per activity for SS and annual endowment for RC). Thus it could be difficult to know how the hospital manage its spending for human resources (what is the exact amount of expenses for each service?). Table 5 presents results for the integrated scenario, we take into account the average value of the maximum number of patients in each service and the maximum value from all replications. For SS the average maximum value is 70.5 patients and the maximum is 74, in this case only 30 beds are available for RC patients. For RC the average maximum value is 52.6 patients and the maximum is 56, in this case only 48 beds are available for SS patients. Both extremes values were found in the same replication so the difference between maximum and minimum value could be 26 beds for both services.

Table 5: Variability of integrated scenario.

Service	Average maximum value	Maximum value
Short Stay	70.5	74
Rehabilitative Care	52.6	56

4.2 Cost analysis

In this part we will focus on cost analysis of Short Stay service because its revenue (the refund system) depends of the activity (Or et al. 2009) unlike Rehabilitative Care which receives an annual endowment (an amount of money for the entire year). The funding calculation of the hospital is based on the DRG which represents an illness type and the severity. Each DRG has a Lower Bound (LB) and an Upper Bound (UB); if $LB \leq SS\ LOS \leq UB$, the hospital receives a Basic Amount (BA); if $SS\ LOS < LB$, there are 3 possibilities:

- If the patient is deceased during his/her stay, the refund is BA.
- If the DRG has a Fixed Lower Penalty FLP then the refund is $BA - FLP$.
- If the DRG has a Daily Lower Penalty DLP, the refund is $BA - (LB - SS\ LOS) \times DLP$.

In the case where $SS\ LOS > UB$, refund is $BA + (SS\ LOS - UB) \times DUP$ where DUP is a Daily Upper Penalty. The aim of this funding method is to incite hospitals to reduce patient LOS in the service.

To estimate the cost of hospitalization, we use an indicator based on a study of the ATIH (Technical Agency of Hospitalization Information) based on 70 hospitals. An Average Cost per Hospitalization (ACH) and a National LOS ($NLOS$) are indicated in this document (and for each DRG) . We consider the Daily Cost (DC) as $ACH \div NLOS$, then the cost spent by the hospital per patient is $SS\ LOS \times SC$.

Each patient needs a DRG to calculate his/her stay refund. To assign a DRG to a patient, we have used the distribution from the data collection. It is important to have a coherent LOS associated with the DRG because refund depends on it. To be more realistic, we have made groups based on LOS (first group with a LOS from 1 to 5 days, second from 6 to 10 days…). Then we determined the DRG distribution for each group and we tested it in the integrated configuration. Table 6 presents the results of the comparison between real and integrated, funding has a good result (error = 4%). The amount of money spent by the SS is satisfying (error = 0.5%) but we cannot conclude while saying whether services earned or lost money because it is based on average value of 70 hospitals. Saint-Etienne Hospital may spend more or less money, but it is a good order of size (both close to 8,500,000 €) and we can estimate the impact of the separated scenario on the cost.

In Figures 7 and 8, we have chosen two indicators which are the extra refund and extra cost with waiting time. Firstly we calculate the refund and the cost only with the necessary SS LOS: from the patient arrival to the moment where he/she should go to the RC. We proceed the same way with the SS LOS including the waiting time between SS and RC. Then we calculate the difference between the two results. In each scenario the difference between extra refunding and extra cost is important. For example, for the 60/44 scenario, the extra refunding is 11,544 € and extra cost is 154,513 €. For the 80/24 scenario, extra refunding is 992,024 € and extra cost is 7,228,040 €; in this case the SS cannot be financially viable. It can be explained by the principle of refunding depending on the activity.

Table 6: Validation of the financial indicator.

Scenario	SS Refunded	SS Spent
Real	8 592 827,78 €	8 707 951,21 €
Simulated	8 260 263.63 €	8 739 057.82 €
Error	4%	0.5%

For example, if the Lower Bound is 3, the Upper Bound is 10, the necessary SS LOS is 5 and the waiting time is 3, the total SS LOS (8) is still between both bounds (3 and 10). In this situation the hospital does not get extra refunding but the patient LOS will be longer. Extra cost is correlated with the total LOS (Figure 8) and scenarios where the RC number of beds is higher than the SS number of beds have not additional spending.

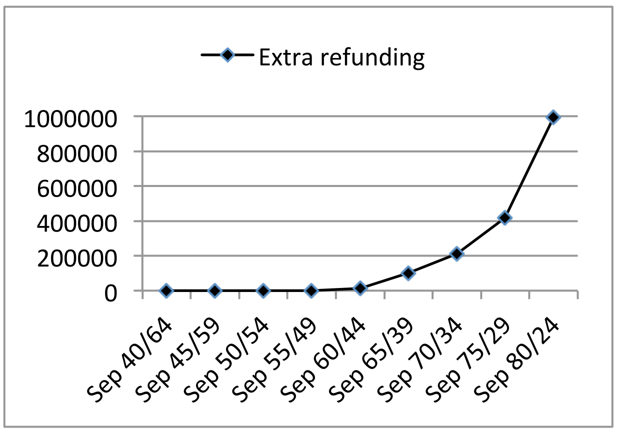

Figure 7: Extra refunding.

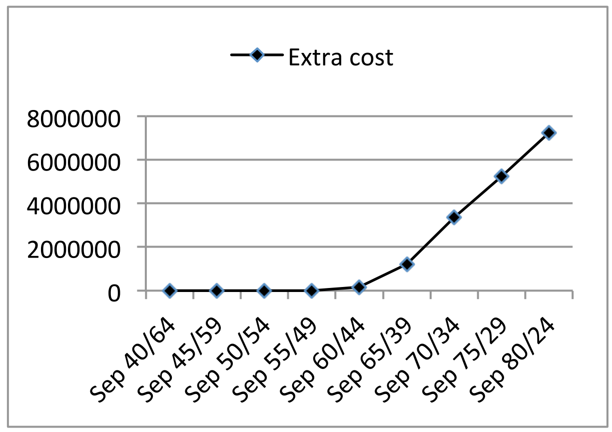

Figure 8: Extra cost.

5 DISCUSSION

The integrated scenario has better results in almost all scenarios (except the occupancy rate, which is still close to the others). This scenario allows the admission of the higher number of patients and also minimizes rejection rate. No patient waits between Short Stay and Rehabilitative Care because the patient stays in the same department and keeps the same bed. When the patient needs to go in RC, the change is only administrative and the elderly does not suffer of being transferred to a new environment, so the quality of care is better. However the number of SS and RC beds can be unbalanced at a given time (Table 3) and it requires a more precise accounting. In addition, in this system the responsible must be the only decision maker for both services.

According to the last arguments it is important to consider the separated configuration, results have shown that the best ratio of bed is 60 SS beds and 44 RC beds (it is the theoretical number of beds in Saint-Etienne). A good sizing is primordial to the efficiency of both services: if the RC is undersized, it creates queues and a lot of patients have to wait between SS and RC. This phenomenon is very important because it causes a longer hospitalization for the elderly and the hospital spends more money than necessary. In Clermont-Ferrand, there are 75 SS beds and around 20 RC beds. This configuration is very close to the separated 80/24 scenario which is the worst one: a lot of patients are refused and important queues (543 patients have waited) are created compared to the number of patient admitted (1052 patients). The total LOS in this scenario is the highest observed and reach 55 days when integrated and separated

60/44 are around 27 days. This means that a patient stays in average 30 days more in this configuration and we have seen in Figures 7 and 8 that the total LOS has a strong impact on the service economic viability.

6 CONCLUSION AND FUTURE WORKS

In this study we have compared two different configurations in two different geriatric hospitals. The integrated care scenario (Saint-Etienne hospital) means that Short Stay and Rehabilitative Care are both in the same department and separated scenario (Clermont-Ferrand hospital) means that both services are located in different departments. We used Discrete Event Simulation to evaluate both scenarios and a design of experiment to study the impact of the bed ratio in SS and RC. The model uses a data collection (one year of hospitalization) from the Saint-Etienne Hospital. Performance indicators are occupancy rates, admissions (admitted or refused), number of waiting patient, total LOS and total transfer time. Then a cost analysis considering the French hospital funding system was performed. The most interesting configuration is the one with integrated care. As authorities recommend separated services, we tested different number of beds in each departments and the best result is 60 beds in Short Stay and 44 beds in Rehabilitative Care (1.36 ratio).

In this paper we assumed that the LOS and the proportion of transfers between services would be equal in integrated configuration. In future work (based on data from other hospitals) it would be interesting to study if these parameters are sensitive and how it would change our results. Furthermore, we did not take into account the step after the hospitalization such as nursing home admission, which may be another reason for bed blocking in RC. Finally it would be interesting to adapt our model and perform the cost analysis in other types of departments in the hospital.

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AUTHOR BIOGRAPHIES

THOMAS FRANCK is a Ph.D. Student at the Center for Health Engineering at Ecole Nationale Superieure des Mines de Saint-Etienne (ENSM.SE), France. He received his Master in Industrial Engineering from the Université Jean Monet de Saint-Etienne (UJM) in 2013. His research interests include applications of modeling, Discrete Event Simulation in health care systems. His email address is thomas.franck@emse.fr.

VINCENT AUGUSTO received his Ph.D. in Industrial Engineering from the Ecole Nationale Supérieure des Mines de Saint-Etienne, France, in 2008. He was a visiting scholar at CIRRELT (Centre Interuniversitaire de Recherche sur les Réseaux d'Entreprise, la Logistique et le Transport), University of Laval, Quebec, Canada in 2009 and in 2015. Currently, he is an assistant professor in the Department of Health care Engineering at the ENSM.SE. His research interests include modeling, simulation, optimization of health care systems and their supply chains. His e-mail address and website are augusto@emse.fr and http://www.emse.fr/~augusto respectively.

XIAOLAN XIE received his Ph.D degree from the University of Nancy I, Nancy, France, in 1989, and the Habilitation à Diriger des Recherches degree from the University of Metz, France, in 1995. Currently, he is a distinguished professor of industrial engineering, the head of the department of Healthcare Engineering of the Center for Health Engineering and the head of IEOR team of CNRS UMR 6158 LIMOS, Ecole Nationale Supérieure des Mines (ENSMSE), Saint-Etienne, France. He is also a chair professor and director of the Center for Healthcare Engineering at the Shanghai Jiao Tong University, China. Before Joining ENSMSE, he was a Research Director at the Institut National de Recherche en Informatique et en Automatique (INRIA) from 2002 to 2005, a Full Professor at Ecole Nationale d'Ingénieurs de Metz from 1999 to 2002, and a Senior Research Scientist at INRIA from 1990 to 1999. His research interests include design, planning and scheduling, supply chain optimization, and performance evaluation, of healthcare and manufacturing systems. He is author/coauthor of over 250 publications (90 journal articles and 5 books). He has been an associate editor for IEEE Transactions on Automation Science & Engineering and International Journal of Production Research. He is general chair of ORAHS'2007 and IPC chair of the IEEE nt WHCM'2010. His email address is xie@emse.fr.

REGIS GONTHIER recieved his Ph.D. degree in medicine from the University Lyon 1, Lyon, France, in 1979, the Habilitation à Diriger des Recherches degree in 1993, and the Capacité National de Gérontologie in 1998. He is the Coordinator of geriatrics activities at the University Hospital of Saint-Etienne since 2003 and professor at the Jean Monnet University (exceptional class in 2012). His e-mail is regis.gonthier@univ-st-etienne.fr.

EMILIE ACHOUR is currently responsible of a Short Stay and Rehabilitative Care service at the University Hospital of Saint-Etienne and assistant professor at the UJM. Her e-mail is emilie.achour@univ-st-etienne.fr.