



HAL
open science

Simulation of Patient-Centred Scenarios for the Improvement of Transportation Service in Hospitals

Rossana Fulgenzi, Simone Gitto, Gianluca Murgia, Elena Pessot

► **To cite this version:**

Rossana Fulgenzi, Simone Gitto, Gianluca Murgia, Elena Pessot. Simulation of Patient-Centred Scenarios for the Improvement of Transportation Service in Hospitals. 23th Working Conference on Virtual Enterprises (PRO-VE), Sep 2022, Lisbon, Portugal. pp.356-365, 10.1007/978-3-031-14844-6_29. hal-04642023

HAL Id: hal-04642023

<https://inria.hal.science/hal-04642023v1>

Submitted on 9 Jul 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License



This document is the original author manuscript of a paper submitted to an IFIP conference proceedings or other IFIP publication by Springer Nature. As such, there may be some differences in the official published version of the paper. Such differences, if any, are usually due to reformatting during preparation for publication or minor corrections made by the author(s) during final proofreading of the publication manuscript.

Simulation of Patient-centred Scenarios for the Improvement of Transportation Service in Hospitals

Rossana Fulgenzi¹, Simone Gitto¹, Gianluca Murgia¹ and Elena Pessot^{1,2}

¹ Department of Information Engineering and Mathematics, University of Siena, via Roma 56, 53100 Siena, Italy

{rossana.fulgenzi, simone.gitto, gianluca.murgia, elena.pessot}@unisi.it

² Institute of Intelligent Industrial Technologies and Systems for Advanced Manufacturing, National Research Council of Italy, via Alfonso Corti 12, 20133 Milan, Italy

Abstract. Hospitals and healthcare facilities are increasingly challenged to ensure an efficient use of resources while achieving a high quality in their services that also maximizes the patients' safety. This is especially important in the case of transportation of patients whose health conditions require the use of appropriate procedures and tools. This work employs a simulation approach to propose solutions for hospitals to improve the organization of the patient transportation service. Resulting solutions are based on the perspective of the service provider and especially driven by patients' needs. By using the Arena software, we analysed the service model in an Italian hospital and the variations in the human, physical and intangible resources that could improve the service performance, with a focus on the operations adding value in terms of time and collaborative behaviours among patients and operators.

Keywords: Simulation scenario; Healthcare services; Transportation service improvement.

1 Introduction

Hospitals and healthcare facilities are increasingly challenged to ensure an efficient use of resources while achieving a high quality in their services that also maximizes patients' safety. Different hospital services and tasks can now leverage a tremendous amount of data collected on daily operations, services, and resources, to be analysed with digital and computerized tools for enhancing the management process [1].

The provision of adequate service quality is especially important in the case of transportation of patients whose health conditions require the use of appropriate procedures and tools. This service uses specialized staff and appropriate tools, such as wheelchairs, stretchers, and hospital beds, which should be assigned in accordance with the health condition of the patients. The limited number of these resources, together with the scarce predictability of the demand for this service and the constraints provoked by the hospital infrastructure (e.g., the limited availability of elevators), makes the optimization of internal transportation extremely important in several hospitals [2]. For these reasons, the (in-hospital) transportation service is often

outsourced to service providers. This choice allows hospitals to concentrate their internal resources on their core activities, such as patients' health, and to take advantage of the economies of specialisation and scale obtainable by the companies that specifically deal with these services [3].

The service provider should guarantee that all transfers are performed in the greatest safety and with the highest degree of care for the patient, as well as in the shortest possible time, with a propensity to optimising and standardising routes and in compliance with current company procedures. To ensure the accomplishment of quality performance, the management and the improvement of the service should take into account the potentialities of digital and computer-based tools. Different patient-centred scenarios that evaluate both the waiting times and the safety of patients could be considered. In this sense, this study aims to understand how the service level for patients is affected by the amount of resources available to the transportation system, and to identify the possible strategies for managing the service demand. To this aim, we defined different patient-centred scenarios according to the variations in the human, physical and intangible resources in the service model of an Italian hospital.

2 The Application Context

2.1 Models for Patient Transportation Services Improvement

The studies on (in-hospital) patient transportation try to optimize the use of physical and human resources involved in the transportation of patients between different hospital units, such as wards, treatment rooms, and operating theatres. Among the operations management approaches proposed in the literature, both Hanne et al. [4] and Kuchera and Rohleder [5] present a software solution that heuristically solves the Dial A Ride problem, thus supporting a more efficient scheduling of the staff involved in in-hospital transportation. Séguin et al. [6] adopt a mixed-integer model to minimize the cost of staff assignment based on a high decentralization, in which the employees are assigned to specific routes, rather than to a more generic area. To reduce both the waiting time of the patient and the related waste of resources involved in internal transportation, Schmid and Doerner [7] propose a systematic and cooperative approach that jointly optimizes the scheduling of operating rooms and transportation services.

While these studies are based on optimization techniques, Segev et al. [8] deal with in-hospital transportation problems by using simulation. They develop an Arena model to estimate the right number, type, and location of the elevators dedicated to internal transportation, other than to study the performance and the robustness of this service in accordance with a different number of elevators. Although simulation may provide a relevant contribution to the analysis of in-hospital transportation, its application in the literature is still limited.

2.2 The Patient Transportation Service of the Santo Stefano Hospital in Prato

The Santo Stefano Hospital in Prato is one of the 13 hospitals belonging to the Azienda USL Toscana Centro (AUSL TC), based in Italy. The centre was created in 2016 following a deep reorganisation of the health service in the Region of Tuscany. The Santo Stefano hospital includes:

- the hospital building, which has 540 beds/beds, 20 short intensive observation areas, 40 dialysis spots, 15 operating theatres, 6 labour rooms and 4 delivery rooms, boasted high diagnostic technology and is organised to meet the different patients' care needs;
- the service building, which is mainly dedicated to logistics, technology centres and laboratories.

The patient transport service consists in transferring the patient, with any aids (infusion pumps, oxygen cylinders, etc.), and the related documentation (medical records, authorisations necessary for diagnosis and treatment purposes etc.), to the ward/service of destination indicated, in most of the hospitals of the AUSLTC. It can be performed using means of transport such as wheelchair, stretcher, bed and corpses trolley. Moreover, it can belong to the categories of scheduled, non-scheduled or urgent transport service, depending on the advance notification of the request by the department to the provider and the maximum time allowed for delivery.

The patient transport service in Santo Stefano hospital is completely outsourced to a Facility Management corporation. The most critical issues that emerged in the analysis of the service include: the presence of delays, highlighted in the majority of the centres of AUSL TC; the limited availability of the service, only at certain times; the lack of service traceability and execution errors. In order to overcome these critical points, an increase in the resources available for the service, a more systematic (and collaborative) organisation, and the adoption of digital tools to monitor the requests for the service were evaluated in this study.

3 The Innovation in the Patient Transportation Service Model

This section describes the steps followed to develop a simulation- and collaboration-based solution for the improvement of the patient transportation service model in the Santo Stefano Hospital in Prato.

3.1 Organisational Analysis of Transportation Service Operations

The requests for patient transportation service in the Santo Stefano di Prato hospital are performed with a centralised process, summarized in Table 1. This process is managed by an Operations Centre (headquarter), made up of porters and telephone operators, who are responsible to forward the requests via mobile phones received from the departments to fellow porters. The advantage of this method, if compared to the other processes that are generally performed in hospitals decentralised general process, semi-centralised process, and decentralised specialized process, is the higher

awareness of the Operations Centre of all the information necessary to choose the most suitable operator to satisfy the request.

The first step of the study was the organisational analysis of the operations belonging to the patient transportation service. Table 1 summarises the main features of operations that occur or could occur in the process, and distinguishes them into value-added (VA) and non-value-added (NVA) activities.

Table 1. The centralised process for requests in patient transportation service.

Operations	Execution time	Human resources	Tangible assets	Operations type
Ward contacts headquarters	50-60 seconds	1 telephone operator; 1 ward supervisor	2 telephones	NVA
Headquarters contact operator	50-60 seconds	1 or 2 operators; 1 telephone operator	1 telephone; 1 mobile phone	NVA
The operator carries out transport	12 minutes	1 or 2 operators; 1 patient	0 or 1 transport vehicle	VA

For example, the first operation is mapped as NVA, considering that queues and long waits are very likely to be generated if several transport requests arrive simultaneously from different wards and/or services, thus affecting services' performance. These activities increase the duration of transport and the number of resources used. They cannot be easily eliminated in the short term, thus they need to be addressed by medium-/long-term improvement plans or major change management activities.

3.2 The Patient Transportation Service Model of the Santo Stefano Hospital

As introduced in the previous section, the patient transport service carried out within the Santo Stefano hospital in the Prato district area is a centralised and outsourced process. The switchboard operators of the Operations Centre handle the sorting of requests, which are both scheduled and unscheduled equally distributed (the latter also includes urgent ones) and are received every day from 08:00 to 18:00. The calls which are not included in this time interval are diverted directly to the porters on duty. In addition, the Operations Centre has 24 porters and 4 wheelchairs available to process requests.

The type of equipment required for transport includes stretchers, beds and corpse trolleys and they are owned by the Healthcare Public Body of the centre of Tuscany, totalling the amount of 150,600 and 2 respectively. The most used type of transportation is the stretcher, located in the Radiology department. Whenever the porter has to carry out a transport, it is necessary that he/she first goes to the Radiology department, and then transfers to the patient's department. This causes an average increase in travel time of about 4 minutes, representing a clear waste in the service. The transport carried out with the bed requires two porters, while the

transport of corpses is carried out with a single porter, as the latter is helped by the mortician.

Finally, with regard to the optimisation policies, the switchboard operators are the ones having a broad knowledge of the precise locations of departments/services and the movements of porters, thus able to choose the best route in terms of time and resources.

Based on data collected on the average number of requests, use of resources along with operations, and average percentages of routings of patients, we created with Arena Simulation the simulation model of the patient transportation service, shown in Fig. 1.

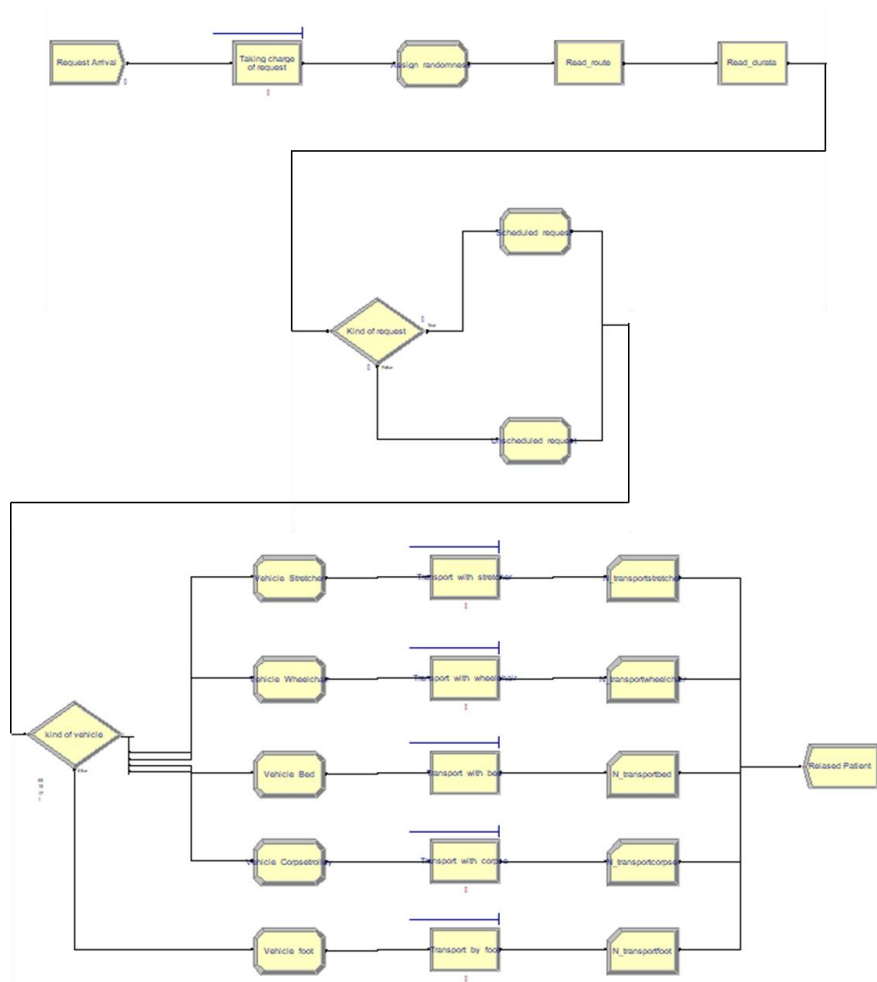


Fig. 1. The patient transport service model AS-IS.

This starts with the request arrives at the Operations Centre, and ends with the release of the patient. Based on data collected, the type of vehicles used were divided according to the percentage of assignments for transportation as: 65% of the probability that entities are routed towards the stretcher, 15% towards the wheelchair, 17% towards the bed, 1% towards the corpse trolley and by the remaining 2% towards transport without any assistance. The simulation model allows to evaluate the strengths and weaknesses, and thus to improve the organization of the patient escorting service in the hospital, based on the perspective of multiple stakeholders and especially driven by patients' needs. Specifically, main areas of improvement concerned the delays, the limited availability of the service, and the lack of service traceability and execution errors. It emerged the need to evaluate how the amount of human, physical and intangible resources could improve the transportation service level, and to simulate the possible strategies into different patient-centred scenarios.

The as-is model was validated by comparing the results obtained from the simulation with real data. Table 2 below categorises the results by transportation means.

Table 2. Validation of the service model as-is

Simulation results			
Statistic Name	Arithmetic Average	Geometric Average	Reality
Number of bed transports	16.50	16.50	31.12
Number of corpse trolley transports	960.00	960.00	278.00
Number of foot transports	1.95	1.95	1.94
Number of stretcher transports	62.92	62.92	58.57
Number of wheelchair transports	14.50	14.50	11.44
Number of arrival request (IN)	96.84	96.84	104.21
Number of arrival request (OUT)	96.83	96.83	104.21

4 Simulation Results and Improvement Proposal

The results obtained by the simulations address the main critical issues identified in Section 2. The main criticalities include: the waiting times of the entities in the various processes of the service model, and especially the waiting time for requests before being accepted; the time required to complete the execution of the various transports; and the average usage of all the resources necessary to accomplish the performance of the service, especially in terms of the difference between the number of transports with stretcher started and finished and the number of transports with stretcher started, but not finished.

The results were divided into Entities, Processes, Queues and Resources for analysis, as shown in Table 3.

Table 3. Results of the simulation for patient transportation service.

Results	
Entities	A request awaits about 5 minutes, before being processed.
Processes	<ul style="list-style-type: none"> The taking over of requests by the switchboard operator causes a waiting time of about 5 minutes. The VA Time necessary to carry out a transport with a stretcher is on average about 14 minutes, because the porter has to retrieve the stretcher in the radiology ward and then carry out the transport.
Queues	The average number of requests waiting to be accepted is equal to 4 units.
Resources	<ul style="list-style-type: none"> The most used human resources during the execution of the service are porters (48%) and telephone operators (74%). The most used material resources are the telephone (74%) and the wheelchair (25%). The critical resources are the telephone and the switchboard operator, slowing down the process execution as they are not able to accommodate multiple requests at the same time. Hiring new human resources could be unprofitable, as less than half of porters are in activity at a precise moment in time.

Table 4 shows the confidence intervals for the most significant results regarding Entities, Processes and Resources of the model in Arena.

Table 4. Confidence intervals for results of the simulation.

Arena Modules' statistics	Confidence interval 95%	
Entity Wait Time	5.00	6.01
Process - Taking charge of request - NumberInQueue	4.02	4.89
Process - Taking charge of request, Queue, WaitingTime	5.00	6.00
Process - Taking charge of request - WaitTimePerEntity	5.00	6.00
Process - Transport with stretcher - TotalTimePerEntity	14.35	14.43
Resource - Operator.Utilization	47.81	48.58
Resource - Telephone Operator.Utilization	36.75	37.30
Resource - Telephone.NumberBusy	73.51	74.60
Resource - Telephone.Utilization	73.51	74.60
Resource - Wheelchair.Utilization	25.01	25.98

The results highlighted some problems in the current configuration of the service and allowed the development of some improvement strategies. By making some changes to the system, it was possible to reduce both the number of requests in the queue and the duration of their processing, and the time required to carry out a transport by stretcher. The strategies consider the essential role of collaborative participation of the service provider personnel, and the need to define patient-centred scenarios, as follows.

First scenario. The first scenario aims to increase the number of transports by stretcher completed and generally to reduce the time required to carry out a transport with this transportation. By allocating the 150 stretchers currently available in a proportionate way in the various wards/services, porters can carry out the transport in a shorter time. From a modelling point of view, it was sufficient to eliminate from the duration of the “Transport with stretcher” process, the part of time dedicated to the recovery of the transportation. With this change the average time to carry out a transport by stretcher has decreased by 4 minutes, becoming just over 10 minutes, and the average number of transports completed by stretcher has increased by 2 units. In addition, this variation has caused a further reduction in the percentage of use by stretcher, from 5% to 3.6%. A final observation concerns the Radiology ward. If the stretchers were no longer stationed in this ward, but were allocated directly at the departure and destination wards/services, there would be an important recovery of physical space and a clear improvement in the working conditions of the healthcare personnel.

Second scenario. The second scenario aims to further modify the first one, in order to reduce the waiting time required to accept a request. The first solution consists in adding one more material resource than the one already present. To do this, it is satisfactory to increase the capacity of the “Telephone” resource by one unit. Having two phones instead of one, the waiting time would be reduced by a considerable amount. Furthermore, it would not be necessary to hire a new human resource, as those already present would be sufficient to guarantee the reception of requests, also coming from the second telephone. Thus, in this way, the workload of the two human resources would be equally distributed. With the addition of the new resource, the waiting time needed to accept a request became approximately 8 seconds (before this change it was 5 minutes). In addition, the number of received and fulfilled requests, increased by 2 units and the number of Work in Progress requests decreased by 6 units. Finally, the results in terms of instant use of resources, show how well the switchboard operators’ workload is balanced, as their occupation is 37%.

Third scenario. The third scenario suggests an alternative solution to the waiting time problem for receiving a request. The basic idea is the following: if the distinction between scheduled and unscheduled requests were made prior or sufficiently in advance, the queue in the reception would be almost completely extinguished. In this way, only unscheduled requests would be accepted by telephone, while those scheduled would be communicated by means of a paper sheet. To implement this solution, it was necessary to make some changes to the model by eliminating the block decide “Kind of request” and halving the amount of incoming requests per time interval. As regards to human and material resources, the following considerations were made:

- the human resource responsible to accommodate unscheduled requests by telephone, remains one, while the second resource deals with the organisation of scheduled transport;

- on the other hand, the capacity of the carrier and transportation resources remain unchanged, as the unscheduled request always takes priority over the scheduled one.

Also with this alternative, the waiting time to accept a request is equal to 21 seconds, slightly higher than that of the second scenario but in any case, much better than the real one. What improves compared to the real model and compared to the second scenario is the difference between the number of requests accepted and completed and the number of requests accepted, but not completed, which is approximately equal to 3 units. Finally, as in the case of the second, the results in terms of instantaneous use of resources show how much the workload of the switchboard operators is balanced, as their employment is 37%.

Results of improvement scenarios. Figure 2 highlights the key improvements in terms of waiting times in the second and third scenarios. The proposed scenarios were evaluated by the staff of the patient transportation service provider, and was characterised by a continuous questioning between them. Moreover, they performed systematic questioning aimed at checking that the patient's safety and his/her life were considered absolute and inviolable priorities.

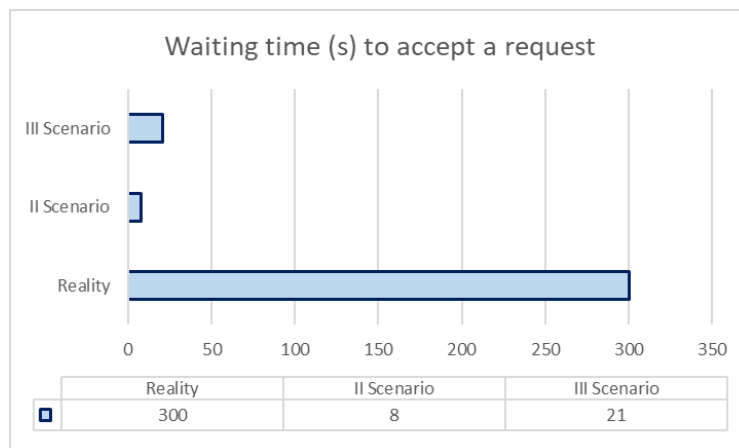


Fig. 2. Comparison of waiting times (in seconds) for accepting a request in reality (model as-is) and in the two proposed improvement scenarios.

5 Conclusions

This work presented a simulation-based approach for identifying possible improvements in the patient transportation service in hospitals. By using the Arena software, we analysed the service model in an Italian hospital and the variations in the human, physical and intangible resources that could improve the service performance,

with a focus on the operations adding value in terms of time and collaborative behaviours among patients and operators. Results show the importance of analysing the organisation and management of transportation service operations with the collection of multiple data, and to consider the collaborative behaviours between the operators and the patients in the accommodation of requests.

Despite the limited generalizability of the detailed data of a single case, the results of the model in terms of Entities, Processes, Queues and Resources can be adopted for the analysis of different hospital services. The application of the simulation in the literature on in-hospital patient transportation service is still limited, but the exploitation of this tool in a participated development project allows to collect several data on service operations from multiple sources, and to map different scenarios according to the organisation's objectives and improvement areas.

Acknowledgments. The authors wish to thank Eng. Alberto Coppi of Azienda USL Toscana Centro (AUSL TC) and the team of Santo Stefano Hospital for the precious support in data collection.

References

1. Oliver, N., Armesh, T., & Tak, I. (2020). Smart hospital services: Health 4.0 and opportunity for developing economies. In L. Pretorius, & M. W. Pretorius (Eds.), *Towards the Digital World and Industry X.0 - Proceedings of the 29th International Conference of the International Association for Management of Technology, IAMOT 2020* (pp. 345-361).
2. Naesens, K., & Gelders, L. (2009). Reorganising a service department: central patient transportation. *Production Planning and Control*, 20(6), 478-483.
3. Mariani, P., Falotico, R., & Zavanella, B. (2014). Outsourcing services in the Italian National Health Service: The evaluation of private and public operators. *Procedia Economics and Finance*, 17, 256-264.
4. Hanne, T., Melo, T., & Nickel, S. (2009). Bringing robustness to patient flow management through optimized patient transports in hospitals. *Interfaces*, 39(3), 241-255.
5. Kuchera, D., & Rohleder, T. R. (2011). Optimizing the patient transport function at Mayo Clinic. *Quality Management in Healthcare*, 20(4), 334-342.
6. Séguin, S., Villeneuve, Y., & Blouin-Delisle, C. H. (2019). Improving patient transportation in hospitals using a mixed-integer programming model. *Operations Research for Health Care*, 23, 100202.
7. Schmid, V., & Doerner, K. F. (2014). Examination and operating room scheduling including optimization of intrahospital routing. *Transportation Science*, 48(1), 59-77.
8. Segev, D., Levi, R., Dunn, P. F., & Sandberg, W. S. (2012). Modeling the impact of changing patient transportation systems on peri-operative process performance in a large hospital: insights from a computer simulation study. *Health care management science*, 15(2), 155-169.