Business Process Reengineering in a hospital context: a case study on deliverables internal transportation

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Abstract — This paper addresses a real-life logistic problem in a Portuguese hospital. The problem consists in studying the possible coordination of two deliverables internal transportation flows, in order to achieve enhanced resource efficiency and overall transportation time reduction. The chosen methodology to address this problem was Business Process Reengineering. This methodology includes analysing how processes are currently operating, redesigning them in order to eliminate wastes and improve efficiency, evaluate how process changes should be implemented to gain competitive advantage. Under this methodology, two distinct scenarios are studied and the results obtained show that both are capable of improving the current processes in the two desired objectives.

Key Words — Coordination, Deliverables Internal Transportation, Business Process Reengineering, Efficiency.

1. Introduction

There is an increasing pressure to deliver healthcare in an efficient manner, and therefore a greater number of healthcare providers are considering material management and logistics high priorities in hospital management (Volland et al., 2015). Hospitals can be characterized as complex distribution networks, and therefore hospital logistics has an enormous potential to improve healthcare. The integration and coordination of different distribution services in hospitals is important since it can lead to operational costs and overall distribution times reduction, enhanced resource efficiency, and effective material management (Figueiredo, 2013).

Hospital Beatriz Ângelo is a hospital composed of several medical units (MUs) situated in different locations in the hospital facilities. The MUs must be provided with different supplies daily, and therefore, several different internal distribution flows, such as medicines, consumables, linen, tray meals, and cleaning, exist within the hospital. Each type of commodity flow is managed independently by a specific service, resulting in uncoordinated delivery to the MUs.

A redesign project for the coordination of two internal flows, medicines and consumables, is proposed by HBA pharmacy in order to try to enhance resource efficiency and reduce overall distribution times. The services responsible to manage these two flows are the pharmacy and warehouse, respectively. The pharmacy is aiming at a reduction in the duration of its staff delivery tasks, so that the assistants are free to perform other required functions. In the current process, two different teams, one from the pharmacy and other from the warehouse, are responsible for the delivery of the needed items to the MUs.

The problem consists in designing the best possible process for the two transportation flows, by analysing both processes and studying the integration of the two delivery circuits.

This paper is organized as follows. In section 2, the context of the study and the problem are described in detail. Section 3 contains a literature review related to this problem. In section 4, the solution method based on a Business Process Reengineering (BPR) framework is applied to this case study, and two proposed scenarios are presented and documented. The gains derived from the implementation of each of the scenarios are reported in Section 5. Finally, the conclusion of the case study and future remarks are presented.

2. Problem Description

The material delivery and collection from hospital services is one of the predominant topics of hospital logistics. It is important that the right quantity of the right supplies reach the correct destination in the hospital at the right time. This is the primary goal of the two delivery flows managed by different logistic centers, which are going to be addressed.

Both flows objective is to replenish the stock levels of medicines and consumables in the MUs in some predefined days. The stages of their process are also similar, the most relevant phases include picking items required by MUs, and transporting and storing these items in the respective MUs. These tasks are assisted by informatics applications, such as an application available in the Personal Digital Assistant (PDA), which supports the picking activity and allows some inspection steps throughout the processes. The items’ transportation to MUs is executed using mobile cars or pallets, and in the warehouse 8 routes are performed by a set of robots. The pharmacy uses cars with different sizes and types, and the warehouse possesses a more homogeneous fleet for the on-foot transportation, composed of just two types of transportation modes, cars or pallets. Typically, each MU demand is quite stable, which means that approximately the same items’ quantity has to be delivered to MUs.

The pharmacy delivery process occurs approximately from 9h30 to 13h00, five days a week. The pharmacy includes two relevant areas for the delivery circuit, the large volumes (LV) and the medicine area. The former’s staff (pharmacy assistants) is responsible for serums’ picking and the latter (pharmacy technician), for the medicines’ picking. The team responsible for the items’ transportation to MUs is composed by the assistants.
working in the LV area. In the current situation, no weekly schedule with the number of human resources (HR) needed for each of the tasks exists, but, normally, the pharmacy assistants’ team size varies between 2 and 5, and the pharmacy technicians between 3 and 5, depending on the pharmacy needs and the time of the year. During the pharmacy delivery process, only a single staff shift exists.

Depending on MUs needs, they must be supplied every day, once a week or twice. Hence, a predefined schedule containing the MUs that should be supplied in each day exists. There is a constraint for the pharmacy delivery process that needs to be respected: the time window for delivering the medicines to the MUs ends at 15h00, and therefore all the deliveries should be performed before this time.

The warehouse delivery morning process starts at 5h00 and ends at 12h45, approximately, in the five workdays. The warehouse staff has different tasks such as reception of supplies, picking and delivery to the MUs, and the team rotates between these tasks every week. There is a weekly schedule which contains the number of human resources needed for each of these tasks. Normally, there is one warehouse assistant responsible exclusively for each task and the remaining staff reinforces these positions. The team size varies between 4 and 6, depending on the warehouse needs and the time of the year. In the warehouse delivery circuit, there are two different shifts – 5h00 to 9h00 (picking and supplies’ reception) and 9h00 to 13h00 (picking and delivery to MUs).

A delivery map for the week is available in order to support the warehouse assistants’ activities and contains the weekdays in which each MU should be supplied; the approximate demand measured in terms of fractions of mobile cars, pallets or robot containers; the human resources needed for each route; the route; the delivery and transportation time; and also the time in which the warehouse assistants’ should initiate the routes. The time window to deliver the consumables to the MUs ends at 13h00.

Although, the two processes have approximately the same steps and work in a similar manner, some differences may be observed. The delivery sites of both circuits differ – in the case of the pharmacy, the delivery is executed in specific rooms inside each MU; whereas in the warehouse circuit the assistants deliver the items in the MUs’ advanced warehouses. The exception to this are 7 MUs, which have a common delivery location. In the warehouse process, the picking step and the transportation of the items to certain MUs happen simultaneously; contrarily, in the pharmacy, the transportation to the MUs only starts when there are no more MUs to perform the picking.

The purpose of this study is to analyse the possibility of a coordination in the delivery tasks of the two deliverables internal flows just described, in order to try to achieve a reduction in the overall transportation times, and improve staff’s efficiency.

3. Literature Review

The problem considered in this paper is a real-life deliverables flow problem in a hospital. Although healthcare facilities are a relatively recent topic for transportation and logistics problems, numerous articles and studies exist on this field, some of the most relevant are analysed.

Augusto & Xie (2009) and Yurtkuran & Emel (2008) studied a pharmacy delivery problem. Augusto & Xie (2009) addressed a hospital pharmacy transportation problem, which consisted in the creation of a transportation and supply plan for each day of the week ensuring balance workloads for transporters and assistants, as well as availability of medicines in each medical service. The problem was solved using a mixed-integer linear programming (MILP) approach to determine a near optimal schedule, which was then combined with a simulation model to redesign the delivery process of the pharmacy. Yurtkuran & Emel (2008) developed a simulation model based on data collected from a hospital in Turkey, in order to analyse its pharmacy delivery system. Two different scenarios with varying factors are investigated, with the objective to minimize the drug delivery time to patients. The best option from the scenarios shows a reduction of 36 percent in the turnaround time of the orders.

Another area is the distribution of dirty linen. Florez et al. (2008) uses a MILP model to find an optimal routing design for dirty linen collection in one of Bogotá’s public hospital under the constraints of resource availability and hygiene conditions. A reduction of 31% in the total distance travelled when comparing it with the current routing design was achieved.

The flow of sterile items is also addressed in the internal-distribution literature. In Rais & Viana (2011), a case related to the flow of sterile instruments between sterilization departments and operating theatres is presented. The optimization of this flow was addressed by developing a cost minimisation model involving transportation and inventory. The authors showed that up to 20% cost reduction is possible.

Kergosien (2013) addresses a transportation problem of various supplies in a hospital complex of Tours. The problem consists in a two level vehicle routing problem. The first is related with the routing problem of a fleet of vehicles distributing supplies to several hospital units. The second level regards the routing of the warehouse employees between the central depot and the building of the hospital complex. The authors have proposed a genetic algorithm and tabu search to solve the first level of the problem. For the second level, the authors proposed an algorithm that simulates the warehouse staff’s behaviour to create the employees’ routes.

The problem considered in this paper is based on a very specific context and finding a good solution that can be successfully implemented in a real situation can be difficult. Therefore, holistic supply chain management is a more qualitative approach to optimize supply chains that is more suitable to apply to this problem. Lee et al. (2011) studied supply chain innovation and how its tools can improve organizational processes and lead to the creation of new operational strategies. Business Process Reengineering (BPR) is one of the techniques that has the ability to improve clinical process and ensure operational improvement (Khodambashi, 2013). BPR in healthcare is associated with the assessment and redesign of logistic processes and the organization of the hospitals’ logistic function (Volland et al., 2015). In literature several authors use
different BPR frameworks as in Mohapatra (2013) and Fitzgerald & Murphy (1996).

Some researchers have studied the applications of BPR in healthcare. Patient flows and processes are widely studied in the literature using BPR methodology. Jansen-Vullers & Reijers (2005) used BPR to perform a study in a mental healthcare institute, whose objective was to improve the patients’ intake process, namely a reduction of both flow and service time. Chou et al. (2012) studied an outpatient pharmacy using analytical tools of process reengineering. The reengineering process led to a reduction in outpatients’ waiting time and improved the quality and competitiveness of the hospital. In Chu & Huang (2013) the reengineering of an outpatient billing process is studied. In the current system, traditional cash billing services are in use, and the aim of this study was to examine a new billing process, which consisted in using smartcard billing. The results showed that the patient waiting time was reduced by at least 8 minutes and this service is more convenient for patients.

Other area of application of BPR is the introduction of radio-frequency identification (RFID) in hospital processes. Kumar & Rahman (2014) demonstrates an application of the RFID-enabled process reengineering in sustainable healthcare system design. A case study in the linens division of a central sterilization services department at a hospital in Singapore is presented. The reengineered process was capable of increasing productivity since the utilization of the staff is much more efficient, and cost reduction. Caldas (2012) studied the introduction of RFID technology in a patient’s food chain in a hospital using BPR. The reengineered process would result in cost and time reduction of the food flow.

4. Solution Method

A BPR framework based on Mohapatra (2013), Fitzgerald & Murphy (1996), Grover & Malhotra (1997) and Rohleder & Silver (1997), is the structure of the solution method, chosen to be applied to this case study. These framework consists of six major fundamental blocks, which are related to: (i) understanding the current processes, (ii) streamlining, identifying the non-value-adding activities and problems, (iii) envisioning new redesigned processes, (iv) designing the technical aspects and (v) social aspects required for the implementation of the proposed modifications to the current processes, and finally (vi) assessment of the proposed redesigned processes in comparison with the current processes. The first step was already investigated in Section 2, where the current processes were described, and the last step is explored in Section 5.

4.1. Streamlining

This streamlining stage is essential to identify the non-value-adding activities and problems with the current processes. A value-added analysis was performed in order to analyse the pharmacy and warehouse delivery processes in terms of value-adding and non-value-adding activities (Figure 1). This analysis showed that 14% of the pharmacy cycle time corresponds to non-value-adding activities, and in the warehouse case to 6%. This analysis combined with process observation and insights from both services staff, allowed the identification of wasteful activities and major problems from both circuits. These are presented below along with their central responsible causes, which were acknowledged through a cause and effect analysis. The problems and wasteful activities are either common for both processes or just bottlenecks found in the pharmacy process.

- Wasteful activities

1. PDA scans: in both processes the employees have to use the PDA for inspection activities after distributing and delivering the items to the MUs. The step of selecting distribute in the PDA is used to control the fact that the picking has finished and the items are now available for transportation to the MUs. However, the step of selecting deliver was initially introduced to be done in the MUs by the nurses whenever they have verified that the items requested were in fact delivered, but this step is currently being performed by the pharmacy and warehouse staff, which has no purpose nor add value to the processes. Also, this step takes a significant amount of time – 38 and 18 minutes daily, in the pharmacy and warehouse circuit, respectively – and is common for the PDAs to start malfunctioning, adding more time to these activities. Cause(s): Low PDA performance and need for PDA operating system re-conception to eliminate the deliver step.

2. Two different teams perform almost the same routes: The pharmacy and warehouse assistants are transporting the respective deliverables to the MUs, performing approximately the same routes (Pharmacy-
MU and Warehouse-MUs). Since the pharmacy and warehouse are located in the same floor, floor -1, and the pharmacy and warehouse delivery sites in the MUs are located within a minor distance, the routes performed by the two teams are considered similar enough for this to be deliberated a case of duplicated effort. There might be a better option by coordinating the transportation of the two deliveries leading to an overall time reduction, being this the objective of this BPR project. 
Cause(s): Lack of coordination between the pharmacy and warehouse, different locations of the pharmacy and the warehouse, and delivery sites in the MUs.

- Problems

(1) Lack of control in the pharmacy process and HR behavior: The non-existence of a delivery map containing the typical daily routes, approximate MUs demands, HR number required per route, elevator that should be used in the route, and typical transportation and delivery times, is disadvantageous for the pharmacy since staff has no guidance or a standardized procedure to follow. Also, if new assistants start working in the pharmacy the training process is more difficult.
Cause(s): Lack of a delivery map and support for route creation

(2) No standardization of MUs nomenclature: The MUs in the pharmacy and warehouse circuit have different nomenclatures, which might lead to difficulties in communication.
Cause(s): Lack of a unified denomination of the MUs throughout the hospital.

(3) Ineffective pharmacy schedule: The current pharmacy schedule does not take into account that the MUs whose distance is shorter or that are located in the same floor should be scheduled to the same day, therefore reducing the time required to complete each route. It is more efficient to schedule the closest MUs to the same days since elevator delay was measured for several routes, and accounts for a significant percentage of the transportation time, 32.50% on average with a standard deviation of 9.63.
Cause(s): Lack of a thorough analysis when developing the current schedule.

(4) Pharmacy mobile cars fleet: The pharmacy items’ transportation to the MUs is completed by using a heterogeneous fleet of mobile cars with different dimensions and capacities. Some routes are performed using transportation cars with very reduced capacities, and therefore it could be beneficial to have a mobile cars fleet consisting of cars with greater capacity so that it would allow for the consolidation of a higher number of pharmacy routes, resulting in the reduction of transportation times. In the current situation, the pharmacy only has available 3 large mobile cars, which is the pharmacy car with greater capacity. Cause(s): Lack of larger mobile cars that allow the transportation of a higher volume of items.

4.2. Creation – Process Innovation

After determining and investigating the main causes of the wasteful activities and problems in both processes, in the streamlining step, two scenarios were proposed. The first one represents only minor to medium changes in the current processes, and the second is a more innovative solution that comprehends both minor and major changes. The choice to present two different solutions was made because it is important to provide alternatives to the current process that possess different levels of required changes for HBA to choose the one that best fit their current needs. Furthermore, it is beneficial to have different scenarios to compare the potential gains and choose the best approach.

**Scenario 1**

This scenario addresses wasteful activity 1, and all the problems identified. However, the objective of this BPR which was to try to combine the pharmacy and warehouse routes is not achieved in this scenario since this would require a great effort from both teams and major changes. Yet, items’ transportation times reduction and enhanced resource efficiency in the pharmacy are expected in this scenario, which was the main motivation behind this reengineering project. This project was proposed by the HBA’s Head of the Pharmacy Department with the central purpose of improving the pharmacy employees’ efficiency in the delivery circuit. And, therefore, is appropriate to have a solution that can achieve this objective by implementing changes only on the pharmacy process. Thus the following actions are assumed to be implemented.

(1) The PDA operating system performance is evaluated in order to assess the current issues with the delays and the PDA malfunctioning. Also, the step of selecting deliver is eliminated.

(2) Introduction of a new pharmacy schedule that takes into account that similar routes (for the same floor) should be scheduled to the same days. This new schedule will adopt the nomenclature already in use at the warehouse.

(3) Introduction of an algorithm in the form of a flowchart that simulates the pharmacy staff’s behaviour and helps to create each day routes.

(4) Acquisition of a new fleet of mobile cars with greater capacity, which allows for the consolidation of a higher number of pharmacy routes, enhancing resources efficiency and reducing transportation time.

(5) Creation of a delivery map for the pharmacy, incorporating the changes introduced.

**Scenario 2**

In this scenario major changes are introduced to the current processes and the main objective of this project, which is the combination of the delivery of the pharmacy and warehouse items, is achieved. Therefore, in this solution all of the wasteful activities and problems identified in the streamlining step are solved. The modifications introduced are presented below.

(1) Creation of a transportation hub to combine the pharmacy and warehouse items'. This hub is an area where the pharmacy items for delivery in that day are
temporarily stored until a designated team transports these to the respective MUs together with the warehouse items for that MU, if there is enough capacity. In case this combination is not possible, due to capacity constraints, the pharmacy items should be supplied in other route. This measure has the potential to eliminate unnecessary visits to MUs since it is possible for an MU to be visited only once, and to decrease the overall time spent on travelling. Having this hub means that there is only one team transporting the pharmacy and warehouse deliverables, removing the duplicated effort present in the current process. In cases of different warehouse and pharmacy delivery sites, the routes can be combined without affecting the staff task in a great extent, since the delivery sites are located within a reasonable distance. To implement this hub, apart from defining the physical, operational and flow characteristics, it is also necessary to take into account that the following procedures need to be altered in the current process:

- Delivery schedules, so that they are as similar as possible. The current delivery schedules of the pharmacy and warehouse have different MUs being supplied in each day.
- Picking and delivery hours so that the phases of the transhipment process are time-balanced, i.e. the mobile cars with the MUs’ items ready to deliver in the transhipment areas should be as much compatible as possible with the ones ready from the warehouse, so that it is possible for each MU to be visited only once if there is enough capacity. If not, the pharmacy items are transported in other route, meaning that all the items placed in the hub have to be transported to their destination MU.

(2) Introduction of an algorithm quite similar to the one from Scenario 1 that simulates the staff’s behaviour and helps to create each day routes.

4.3. Technical Design

In this step, the technical design required for the two previously proposed scenarios is presented. This include hardware, procedures and plans for facilities enhancement that can possibly be needed for the envisioned reengineered processes (Mohapatra, 1997).

Scenario 1

The modifications to the current pharmacy process comprise mainly alterations in the current procedures, delivery schedule and tool to assist the creation of the employees’ routes – current equipment, mobile cars – and a system modification, PDA system.

New Delivery Schedule

In rescheduling activities is important to consider the goals and constraints that the schedule should follow to obtain a good and effective schedule (Snoo, 2012). In the pharmacy case, there is no particular specification or constraint for the rescheduling process, except that: the scheduling horizon is one working week, this is from Monday to Friday; and the MUs frequency of supply per week, which is already defined.

These soft constraints combined with the specific goal of introducing just slight changes to the current delivery schedule, because the current one includes some MUs preferences, resulted in having no need to translate this problem in a mathematical formulation or using scheduling algorithms. More, these algorithms are often used on more complex problems and in scheduling with tighter delivery time windows or limited resources, which is not the case. And, therefore a more empirical approach based on the pharmacy process observation was chosen to be the most suitable method to perform the rescheduling activity. This empirical approach took into account, the level of the MUs, the routes (the elevator that is used by the assistants to transport the mobile cars from the pharmacy to the MUs), the proximity of the MUs location and their demands. The new proposed schedule was obtained by introducing modifications regarding these aspects, and is more day-balanced than the current one, which is beneficial both for the hospital and the employees because well-balanced workload normally leads to higher productivity.

Employees’ Routes Tool

This tool is in the form of a flowchart algorithm that simulates the assistants’ behavior and has the purpose of assisting the pharmacy assistants in the creation of the daily routes. The reason to choose this method for routes creation is not to obtain the optimal routes, but to get a robust and flexible method that would work well if the MUs demands are not completely stable. This algorithm is based on a set of heuristics, which do not guarantee an optimal solution, but permit the generation of a feasible solution respecting these heuristics.

In the algorithm (Figure 2), a route is created according to two types of events: the picking phase of the destination MU has ended or the end of a route. After one of these events, the algorithm operates like a sequence of filters, which uses a series of heuristics in order to select MUs to assign to a route. These heuristics were constructed for the pharmacy particular case based on process observation, and include the following: whenever the mobile car capacity to be used in the transportation has not been reached, the order that should be followed to choose an MU to integrate a route is - MUs from the same level, and only after this MUs from different hospital levels. Since this algorithm is quite simple, it can be used on a daily basis without software support. Also, having software support would increment the time taken to create routes since data about MU’s demands would have to be introduced, instead of experienced assistants making quick decisions following the flowchart available in the pharmacy.

Mobile Cars Fleet

A study was performed in order to assess if acquiring new larger mobile cars would have the desired outcome of consolidating a higher number of pharmacy routes. A route creation excel support, which follows the flowchart algorithm just presented, was designed to simulate the routes for each weekday. The demands value used for this simulation was the
typical demands volume obtained by multiplying the measured demand for each MU in terms of the mobile cars occupation and the volume of the respective transportation car.

It was considered that the preferred transportation modes were the pharmacy large mobile cars, and the warehouse cars (which are the ones with higher capacity in HBA) whenever a MU route could not be transported using a single large car, and that there was no restriction in the number of these mobile cars.

The results obtained showed that the number of daily routes could be reduced on average 32.62% by acquiring 3 new warehouse cars. Also, an increased resource efficiency can be achieved because in a single route an assistant completes the delivery of a higher number of MUs. In the current situation the average daily human resources needed per route is 1.41 and in this scenario this number drops to 1.10.

**Scenario 2**

The alterations to the current process introduced by this scenario encompass plans for facilities enhancement, the transportation hub, which leads to alterations in the delivery schedules of the pharmacy and warehouse; and the introduction of a tool to assist the process of creating routes.

**Transportation Hub**

The plans for the creation of the transportation hub in the hospital facilities include decisions on three groups of characteristics: physical, operational and flow characteristics (Van Belle, 2012).

1. **Physical characteristics**

Regarding physical characteristics, decisions about hub location and layout were performed. The location is an available area in HBA with 8m$^2$ and situated in level -1. The space available is in a perfect location to allow the consolidation of the routes with a low transportation cost, since it is situated in the corridors of the pharmacy and warehouse, enabling the assistants of both services to reach the hub in a reduced time. Most of the routes performed by the warehouse, use the elevators located in the area of the available space, which

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**Fig. 2.** New proposed flowchart algorithm for route creation in the pharmacy.
means that the movements warehouse-hub-elevators are optimized.

The hub dimensions are reduced, which led to the following decisions: the hub is a space to temporarily accommodate the pharmacy items before transportation to the respective MUs, meaning that the hub only has to allocate the daily pharmacy items; and, the MUs located on level -1 should be directly supplied by the pharmacy, without storage in the hub, since the time required to transport these MUs mobile cars to the hub and then from the hub to the respective MUs is higher than the pharmacy directly supplying these MUs.

To calculate the daily space required by the pharmacy items, a pharmacy rescheduling process was performed so that the pharmacy and warehouse schedules are as similar as possible for the MUs whose mobile car occupation is below 100%, and therefore their delivery could be coordinated. Considering the new pharmacy schedule, estimations of the daily volume required were performed, to obtain the storage capacity that should be available in the hub to permit the accommodation of the MUs daily demand.

After analysing different alternatives for storage and hub layout, it was considered that the preferred storage option was rack shelves and for hub layout, a variation of the single-block layout (Henn et al., 2013), which is displayed in Figure 3, was the one that showed better results in terms of picking aisles width, area for loading/unloading of mobile cars, and storage capacity.

![Projected hub layout using SmartDraw®.](image)

2. Operational characteristics

The operational decision that should have an impact in the functioning of the hub is related to the mobile cars used by the team responsible for the pharmacy and warehouse items' delivery. Currently, the car fleet is heterogeneous, comprising cars with different capacities. However, with the primary goal of consolidating the two services' delivery, the option of having a fleet of mobile cars with greater capacity to allow the transportation of both pharmacy and warehouse items was considered.

An analysis consisting in an evaluation of the pharmacy and warehouse MUs that could be potentially incorporated in the same route was performed in order to find the more suitable transport mode for the hub. It was considered that if the items' volume surpasses the car capacity by 10%, it would be possible to join these routes, since the demands used for items' volume estimations are typical demands that contain a certain level of uncertainty along with the fact that they are given in terms of fractions of mobile car and therefore are normally overestimated. The results of this analysis showed that the mobile cars used by the warehouse are the mode of transportation already available in HBA that has the highest capacity and should be preferred as outbound transport mode of the hub. The utilization of warehouse cars allows the consolidation of 11 MUs routes, and only 5, due to capacity constraints, cannot be performed in the same route.

3. Flow characteristics

Regarding flow characteristics, two important aspects need to be defined when designing a transportation hub – arrival pattern and departure time.

The arrival pattern is related to the way the inbound vehicles arrive at the hub. The objective is to follow the warehouse schedule as rigorously as possible, and therefore the arrival pattern of the pharmacy mobile cars must be as consistent as possible with the pre-established warehouse delivery times. A picking timetable for the pharmacy was defined so that the picking of the MUs whose mobile cars should be delivered in the hub at an earlier time is performed first. To create this timetable, the routes for each day were obtained using a flowchart algorithm similar to the one from scenario 1. In this case, the route creation algorithm uses the following set of heuristics to select MUs to assign to a route: demands to the same destination MU from the warehouse and the pharmacy, MUs from the same level, and lastly MUs from different levels in HBA facilities. If a car corresponding to a certain MU is already with full capacity, the route can be initiated to the respective destination MU, without passing through the transportation hub.

This method is even more suitable in this case since we are dealing with two demands that have some uncertainty, and therefore it is beneficial to have a flexible and robust method to create the team routes.

It was considered that the preferred transportation mode, was the warehouse mobile car, and that if the MUs total delivery volume only surpasses the car capacity by 10%, these MUs could be incorporated in the same route. The results allowed the creation of the pharmacy picking timetable, and showed that the changes introduced in this scenario allow for an average daily route reduction of 30.86%.

Regarding the departure time of both the inbound and outbound vehicles in the hub, the following occurs: the inbound mobile cars should leave the hub once the assistant has unloaded the transportation car and stored the MU(s) items in the rack shelves; for the outbound warehouse mobile cars, the departure times have to respect the time windows to deliver the items to the MUs, and the delivery times already established for the warehouse MUs. However, some delivery times were modified having into account the pharmacy picking start time, the picking time per MU, and the time taken to transport the MUs items to the hub. It was also defined that if any inbound pharmacy car arrives later than the times pre-established, the outbound warehouse cars should wait and perform the routes of other MUs, which are ready for delivery. The exception to this is the pharmacy items not being in the hub before the time.
necessary for the team to complete the delivery during the warehouse delivery time window. In this case, the outbound transportation car should leave the hub and the pharmacy MU items are distributed in other route.

### 4.4. Social Design

This phase of the framework is remarkably important and refers to the social dimension of the proposed reengineered scenarios, which contribute to the success of the projected technical design. It comprises the changes that should be introduced by the two scenarios from the staff’s point of view. Also, the HR required for the correct functioning of the redesigned processes is considered along with possible staff resistance to the changes proposed.

**Scenario 1**

This scenario selected modifications are not expected to alter the daily routine of the pharmacy assistants in a great extent since they perform the exact same tasks. Moreover, as aforementioned, since this BPR was proposed by the HBA Head of Pharmacy, the pharmacy staff is more willing to change, and the majority of the employees are aware of some of the problems and wasteful activities pointed out. However, proper communication of the changes proposed, with the reasons behind each decision and its benefits might be useful for staff collaboration, which is essential to guarantee the success of this proposed solution.

In terms of the number of human resources required for this solution, two options exist and HBA pharmacy should choose which one best fits their needs:

1. All the assistants currently performing the transportation and delivery to MUs task, normally 3, continue performing this function, meaning that the duration is greatly reduced, and the assistants are free to perform other tasks after this is completed.
2. Only a fraction of the assistants (1 or 2, depending on the weekday since there are routes on two days that require two human resources), perform this task, which means that the duration is higher than in the first option, but part of the assistants become available after the picking task and can execute other functions.

**Scenario 2**

In this scenario, substantial alterations to the current processes are proposed, and therefore, the social dimension of this solution must be carefully considered. With the transportation hub introduction, both the pharmacy and warehouse delivery process suffer transformations. The major alteration in terms of the staff perspective involves the creation of a new team responsible for the combined delivery of the pharmacy and warehouse demands. This means that this team is in charge of the routes passing through the hub. To dimension the delivery team and evaluate the number of required HR, the routes were considered fixed jobs and the employees, resources. The objective is to perform all jobs, while minimizing the number of resources used.

The number of required employees, which are the team responsible for the pharmacy items and consumables delivery, was computed using a greedy approach as in Kergosien et al. (2013). This approach operates in the following mode, for each day: in the hub routes list ordered, a route is assigned to an assistant, and withdrawn from the list. Then, the next route is tested, if this cannot be assigned to the same assistant, the next route on the list is tested. This process repeats itself until the lists for the weekdays are empty. When this occurs, the maximum number of employees required is found. In the process of assigning routes to assistants, it was considered that the delivery times established had an upper and lower tolerance of 30 minutes, so that the number of assistants performing the hub routes can be further minimized. As the daily list of routes is small, this approach was performed manually using Excel as a support. The routes duration was calculated by summing transportation and delivery time for each route. The transportation time was estimated by having into account the distance between MUs, the average walking speed and the elevator delay, whenever no data was available from the current process. For the delivery time of each MU, data from the current processes was used since route combination maintains this information unaltered.

The results of this greedy approach showed that on 3 weekdays a single assistant is required to perform the hub routes, since it is possible for all the routes to be performed respecting the warehouse time window, and within the 30 minutes’ tolerance for the warehouse delivery times. On one, two assistants are required because one route needs to be performed by two human resources. However, this is the only route that needs to be performed by two human resources, the remaining routes can be executed by the same assistant. Lastly, for the other weekday, the scheduled hub routes require two assistants.

The warehouse routes daily duration was calculated, so that the assessment of the total number of HR required to complete all delivery routes could be performed. For all days, it is possible for a single assistant to complete the hub routes and other the warehouse routes within the time window to deliver the consumables. For the days in which some hub or warehouse routes require two HR, these two assistants responsible for the transportation to the MUs should effectuate the routes together. Given that the number of assistants necessary to complete the hub routes is reduced, this team can be composed exclusively by warehouse assistants. The pharmacy assistants only need to execute the picking and transportation of items to the hub, and the delivery of the MUs located in level -1, which are scheduled to the same day and route. This means that they are free to perform other needed functions after completing these tasks. In the current situation two assistants are responsible for the warehouse routes, meaning that it is possible to maintain this number unaltered.

Regarding the changes introduced to the current processes by this scenario, it is expected that a slight resistance to change may occur, and therefore, as in scenario 1, an appropriate and clear communication and explanation of the alterations that will be introduced is crucial for employees’ acceptance and the success of this scenario. This is more relevant to the warehouse.
staff since they are the ones that will have to change their daily tasks in a greater extent. The pharmacy assistants’ tasks modification is not likely to give rise to resistance because the alterations to the current process are only related with having an order for MUs picking and to transport the MUs items to the hub instead of to the MUs. In the warehouse case, the staff will be responsible for the combined delivery of pharmacy and warehouse items, and therefore, one of the assistants will be responsible for the hub routes, which is a function that varies significantly from the one already performed.

5. Results

The two scenarios proposed affect the deliverables internal transportation process in four dimensions: reduce cycle time, mainly transportation times; eliminate non-value-adding activities; enhance resource efficiency and consolidate a considerable number of delivery routes. These modifications can be observed in both scenarios, the difference is that in scenario 1 these improvements are for the pharmacy delivery process, and in scenario 2, for the overall deliverables transportation process.

In scenario 1, the pharmacy process changes are related to alterations in the delivery schedule, creation of a tool in the form of a decision tree to assist routes creation, acquisition of new larger transportation cars, and eliminating the need to select deliver in the PDA. This means that in the process steps, no activity changes apart from the elimination of the selecting deliver in the PDA task, which is shaded in purple in Figure 4. Nonetheless, the routes transportation times suffer alterations comparing to the current process in result of the changes introduced.

The changes introduced in this scenario, although minor, have a profound impact on the pharmacy process. The redesigned process is distributed along 5 hours and 53 minutes versus the 6 hours and 52 minutes of the current process, which represents a time reduction of 59 minutes. The non-value-adding activities time also reduced from 1h08 minutes (considering the 10 minutes, which were wasted in the picking step of the current process due to PDA malfunctioning) to 20 minutes. However, the main improvement is related to the fact that the majority of the routes, i.e. the transportation and items’ storage in the MUs, in this scenario can be performed by just one pharmacy assistant. The average daily human resources needed per route drops from 1.41 in the current situation to 1.10, this means that resource efficiency is increased in this scenario, and that a lower number of assistants are required to perform all daily routes, resulting in the availability of the other assistants to complete other tasks. Also, it is observed an average daily route reduction of 32.62%.

In scenario 2, the proposed modifications to the current processes include the creation of a transportation hub, which leads to alterations in the delivery schedules of the pharmacy and warehouse, and the introduction of a tool to assist the process of creating routes. The activities which suffer alterations due to these changes are shaded in purple and correspond to the redesigned steps in the processes, in Figure 5.

The summary of the changes introduced in both processes’ steps by this scenario is presented next.

- The step of selecting deliver in the PDA was eliminated for both processes.
- The pharmacy does not transport and store items in the MUs, this task is now concentrated in the warehouse staff. The pharmacy assistants are only responsible for transporting and storing the MUs’ items in the hub. Exception to this are the MUs located in level -1, which are all scheduled to a single route on Wednesday.
The warehouse is responsible for the transportation of the pharmacy items. This leads to the existence of two different types of routes, as depicted in the redesigned warehouse process: (i) hub routes, which are the ones in which the aggregation of pharmacy and warehouse items is possible, and consequently the assistants pass through the hub to collect the pharmacy items before initiating the route; and (ii) warehouse routes, which comprise the routes whose consolidation with the pharmacy is not possible, and therefore the assistants can go directly to the destination MU without going to the hub.

The changes of this proposed scenario have a wide impact on the process, as a whole. The pharmacy and warehouse redesigned processes are distributed along 12 hours and 40 minutes versus the 13 hours and 56 minutes of the current process, which represents a time reduction of 1 hour and 16 minutes. The total non-value-adding activities duration is reduced from 1 hour and 42 minutes to 26 minutes, considering that approximately 10 minutes in the picking activity corresponding to wasted time in both processes is eliminated. However, the main improvement is related to the fact that the total cycle time of the pharmacy process decreased from 6 hours and 52 minutes to 5 hours and 16 minutes, which means that the pharmacy assistants are free to perform other required functions 1 hour and 36 minutes before, comparing with the current situation. And, this decrease of the pharmacy cycle time only resulted in a 20 minutes' increase in the warehouse process total time.

Other important outcome of this scenario is the 30.86% route reduction, and the major enhancement of the resource efficiency. In the current process, 5 to 6 employees are responsible for the pharmacy and warehouse delivery (2-3 for the pharmacy and 2 for the warehouse), and with the creation of the hub and the consolidation of the pharmacy and warehouse routes, this job can now be completed by two human resources, resulting in reduced operational costs.

6. Conclusions and Final Remarks

This paper presents a real-life problem of two deliverables internal flow in a hospital. The problem consists of analysing these two delivery processes and propose a solution that leads to the reduction of transportation times and enhance resource efficiency. To solve this problem, this paper proposes two different scenarios under the BPR methodology, which contain different levels of required modifications to the current processes. The results, which were based on real data available or measured in hospital context, and estimations, prove that the two alternatives proposed provide better results regarding the two objectives than the current situation. These results will help the hospital in establishing redesigned processes, which will improve these two delivery internal flows.

The major limitations of the solutions proposed, are the estimations made for the MUs demands and transportation times between MUs when no real data was available, and considerations such as the tolerance of 10% in the transportation car volume and the flexibility in delivery times, in scenario 2. This means that is possible that a gap between the theoretical results obtained and the reality exists, and adjustments may be necessary. Therefore, implementation is the next important step to confirm the quality of the results presented in this paper.

Future research should focus on evaluating the impact to the MUs of changing the pharmacy delivery sites to the advanced warehouses where the consumables are delivered. If this modification could be implemented, scenario 2 would be smoother for the warehouse assistants responsible for the items' transportation to MUs, and would inevitably result in lower transportation times, making this scenario more feasible.

Also, exploring these BPR methodology for other internal processes in the hospital could be beneficial, since this was clearly valuable in analysing the processes and improving them significantly.

References


