Exploring Opportunities for Improving the Portuguese Patient Transport Management System

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Abstract

The Patient Transport Management System (PTMS) is an online integrated platform, developed by Link Consulting, which supports all activities and management procedures inherent to the programmed transport of patients. In the last decade, PTMS was developed and adopted by several National Health Service (NHS) entities and is currently used in the management of non-emergency transport of patients in almost all the primary care network.

This work aims to develop and implement a methodology to analyze opportunities for improvement in the PTMS algorithms taking into account potential impacts on multiple system stakeholders. In this context, it is intended to contribute to the literature on programmed transportation of users through the development of a methodology to explore alternatives in logic and parameters of transport organization algorithms, taking into account how these affect the transport system objectives and directly or indirectly involved stakeholders. Thus, a methodology with the following components was constructed: (I) Conceptualization of system algorithms and analysis of its stakeholders and; (II) Mapping of proposed algorithms alterations and definition of key performance indicators definition; (III) Simulation and analysis of the impact of changes on multiple objectives and system stakeholders.

The proposed methodology has been applied to the PTMS in order to generate information that supports Link Consulting company in identifying opportunities for improvement of this system. Through the obtained results, it was observed that a decrease of maximum time intervals between medical services of the same transport group would introduce improvements in PTMS that meet the interests of its multiple stakeholders.

KEYWORDS: Information Systems in Healthcare, Programmed Transportation of Patients, Stakeholder Analysis, Impact Analysis, Conflict of Multiple Objectives

1. Introduction

In Portugal, the National Health Service (NHS) has as one of the fundamental objectives of its policies to provide equal health care access opportunities for its citizens [1]. Thus, it is responsible for providing a transportation service that allows those who by themselves are unable to travel to health service providers, due to either economic insufficiency or disabling medical condition [2][3].

In order to meet this need, an online platform developed by Link Consulting company is implemented throughout the primary health care network. This platform integrates all activities and management procedures for the transportation of non-emergency patients, and is termed the Patient Transport Management System (PTMS).

The PTMS presents itself not only as a tool for patient transportation management but is also responsible for forming patient transport groups, for assigning the carriers entities to it and, finally, for accounting the costs generated by the transport. These actions are carried out through algorithms that meet a set of rules and constraints, on which the analysis of this work is based.

This integrated information system encompasses all stakeholders involved directly in the process of non-emergency patient transportation, namely: requesters, carriers, healthcare providers and also supervisors. As such, the PTMS has a service-oriented architecture, since it is constituted by a set of independent services that communicate with each other, to create a functional application software [4].

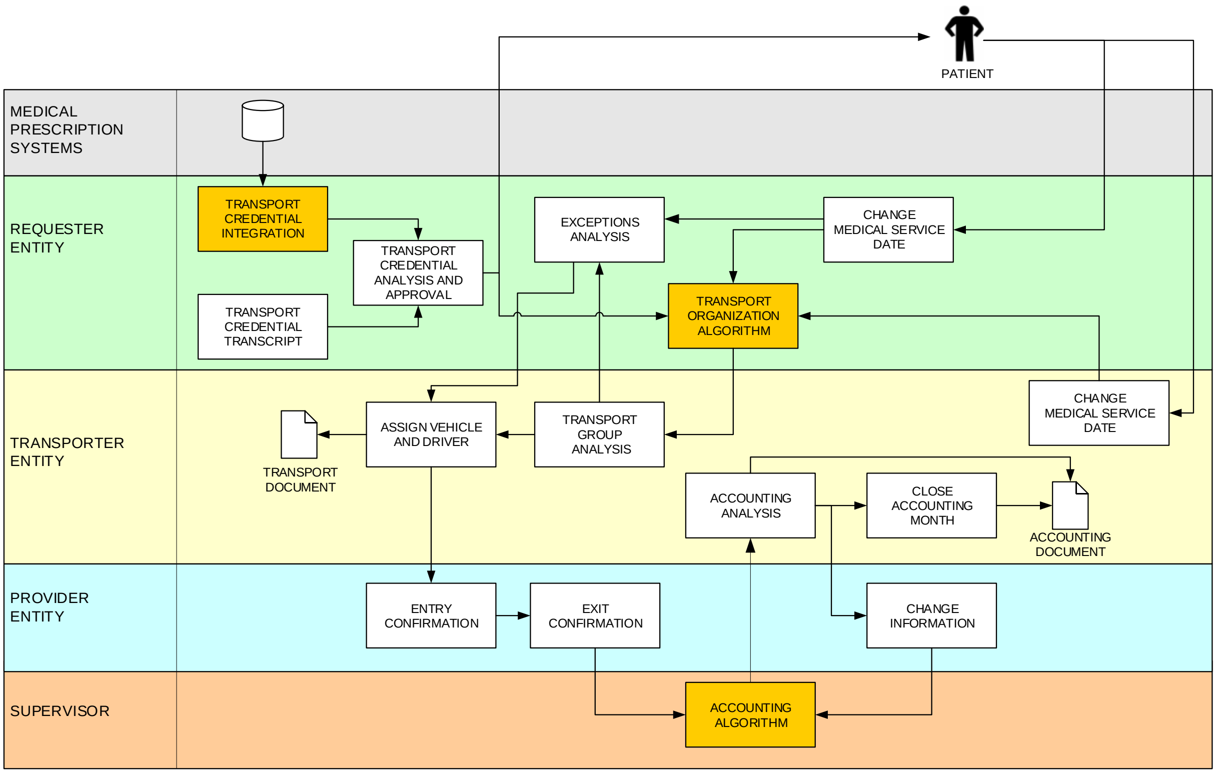


Figure 1 – PTMS operations diagram [5].

To better understand the different stages of the process of organizing, planning and accounting for non-emergency patient transportation and the role of the multiple stakeholders throughout these processes, the following diagram of PTMS operations is presented (Figure 1). Furthermore, a brief description of the several steps of patient transportation process will be given. The first step of this process is the recognition, by a clinician, of the transport user's need to attend a medical service. Then, the requester entity is responsible for the integration of the transport request in the PTMS. The request contains information about the user, the type of medical service, sites of pickup and delivery, features and special requirements for the transport. It should also be noted that this entity is responsible for the costs of transports that itself has prescribed. Once approved by the requester entity supervisor, the transport requests can integrate the PTMS transport grouping algorithm, as transport credentials, in order to be grouped according to a set of criteria and requirements. After that, the transport groups can integrate the assignment carrier entity algorithm. Once each transport group has a carrier assigned to it, the carriers have access to this information and have the option to approve or reject them. When a transport group is rejected, it is the responsibility of the Region Health Administration (RHA) to manually assign a responsible carrier for it. The approval is tacit if the transport group is not rejected until 15.30 p.m. on the day before its completion. Afterwards, the carrier entity has to assign a headquarter, vehicle and driver to each transport group approved. It is the responsibility of this entity to contact the user, in order to match the time of pickup. It is the responsibility of the provider entity to confirm in the PTMS the users' hours of entry and exit, as well as to point out the non-operation of transport, where appropriate. Finally, it is possible to proceed with the accounting for each transportation request completed, using the PTMS accounting algorithm, whose results are reviewed and approved by the carrier entity. At the end of each month, each carrier entity issues a document generated by PTMS with its accounting, which is attached to the invoice to be sent to the RHA.

After this brief description of the system operation, it is possible to understand that the four stakeholders highlighted in the diagram in Figure 1, which act at different stages of the programmed transport process, correspond to four distinct types of system users. Thus, the well defined and independent role that each one has in the PTMS and the multiplicity of direct agents in this system becomes evident.

Given the socio-economic context in which the country currently finds itself, with constant pressures to reduce costs, combined with the intent of Link Consulting in improving its product, led naturally to the demand, by this company, of opportunities to improve the current functioning of PTMS algorithms. However, it is possible to deduce that a system with a context such as the PTMS has an associated set of complex challenges, since it deals with a wide variety of stakeholders and objectives which sometimes come into conflict.

Thus, the need to analyze opportunities for improvement that can contribute constructively to the development of this system, integrating the views and interests of the multiple stakeholders of PTMS was recognized. Consequently, it was pertinent to develop a methodology to analyze changes in logic and parameters of PTMS algorithms in order to realise their impact on the system's multiple objectives and stakeholders and to evaluate their feasibility. This way, the generation of useful information to support Link Consulting in analyzing opportunities for improvement of the PTMS was expected.

2. Literature Review

After identifying the scope of PTMS and its global features a literature review was conducted in order to understand how programmed transportation of users is approached in the literature and to identify similar systems to the PTMS, in a healthcare context. The aim of this literature review was to find methodologies that could support and contribute to the construction of the methodology that this work proposed to develop.

In order to gather relevant information on this matter, a research protocol was conducted by consulting online databases such as Pubmed, ScienceDirect and Google, using the following keywords "patient transport system", "patient transportation", "healthcare dial-a-ride problem "and" pickup and delivery problem".

None of the methodologies and approaches found in the literature met in full the purpose of this study, due to specificity of a system as complex as the PTMS. It is also important to note that all systems and approaches found addressed the programmed transportation problem as a route optimization problem. This is contrary to the scope of this work which intends to search for opportunities for improvement within the PTMS current operation. However, some methodologies did reveal the importance of decision support tools for the analysis of programmed transportation systems improvement [6][7][8] such as the use of simulation models.

Therefore, the need of developing a methodology suitable to PTMS requirements and stakeholders was clear. In order to achieve that there was also the need to develop a research to find frameworks and methods that could support each of the stages composing the methodology to be proposed. The main results of this review are summarized as follows.

2.1. Stakeholder Analysis Methodologies

Given the multiplicity of PTMS stakeholders it is fundamental to conduct a stakeholder analysis in order to identify and categorize the many stakeholders of this system and to understand their level of participation.

A stakeholder analysis methodology shall must necessarily have three steps [9], described as follows. A first step, where the system in focus and its borders are identified (context analysis). A second step, where the different methods of stakeholder analysis are applied in order to identify the system stakeholders and their interests. At this stage, a categorization of stakeholders, according to their interests and engagement as well as an analysis of the relationships between them it is also made. Finally, in the last step, some recommendations should be given as communication strategies appropriate for each stakeholder profile, depending on the categorization made in the previous point. Thus the support by the stakeholders in the changes to be made to the system is intended to be achieved.

After being identified, stakeholders can be categorized according to their organizational location: internal ones, when operating within the system boundaries; interface ones, when interacting with the external environment; and external ones, those who can contribute, compete or have some special interest in the organization/system operation [10].

There are several methods for classifying the position of stakeholders in the system in which they operate. We chose to highlight the method of mapping stakeholders in an interest and influence matrix, since it is a visual tool that allows straightforward perception of several interest points in a decision context, such as: (1) Engagement level of each stakeholder in the system; (2) Patterns in the stakeholders distribution in the matrix; (3) Identification of potential resistance to change; (4) Alliances prevision [9]. Therefore, the information gathered from this matrix allows the decision maker to adjust communication strategies to each stakeholder profile, in order to have support or to prevent alliances that may be unfavourable to a minority group in the system or to favor others deemed to be convenient. This method consists of mapping stakeholders in a matrix of four quadrants, each associated with a stakeholder profile. Its two axes represent the level of interest and influence of the mapped stakeholders.

2.2. Identifying System Objectives and Defining Key Performance Indicators

After stakeholder analysis, it is essential to structure the system objectives with accuracy in order to understand how these are correlated with the several stakeholders. There are two types of objectives: fundamentals and means [11]. In a decision context, a fundamental objective is an essential reason for interest in a system or organization. Means objectives, in turn, have an interest in how they relate to the fundamental objectives and influence their success. However, in situations of decision analysis or evaluation of alternatives, the focus of the study should be on the fundamental objectives. As such, they represent a set of objectives for which performance indicators should be defined [11]. Means and final objectives must still be considered in the analysis, as they allow alternatives to be related to their consequences. Regarding the definition of performance indicators, they should be defined concerning the following characteristics: measurability, operability and intelligibility, to enable a clear and accurate system analysis [11]. After identifying system fundamental objectives, it becomes possible to establish the focus of analysis when simulating changes to the system algorithms. The impact of these will thus be measured by a greater or smaller success level achieved for each of the objectives and associated stakeholders. Therefore it becomes possible to analyze the adequacy and viability of the proposed changes to PTMS. Hence, it is essential to define key performance indicators that make the impact produced by the simulated changes in the system measurable, according to the aforementioned characteristics.

3. Methodology Framework

In order to generate information to support the company Link Consulting to analyze opportunities for improvement of PTMS algorithms a methodology suitable to PTMS features and objectives of this work was built. This allowed the impact of alterations in the functional logic of PTMS algorithms and parameters in the multiple objectives and stakeholders of the system to be analyzed. Therefore, different methods were used, with theoretical basis in the literature, which combined differentiate the proposed methodology from existing techniques. Specifically, the methodology proposed is a multimethodology [12] as it combines different methods and techniques that, when taken together, allow analysis of the system as a whole more effectively without disadvantages to any of its components.

Throughout the several steps of the proposed methodology (Figure 2), the adoption of a socio-technical approach was decoded. As this work is intended to support the decision of Link Consulting it is accordingly relevant to adjust and assess the different analyzes according with the needs and viewpoints of the company. Thus, in developing this methodology two equally important components were considered: social and technical [13]. Regarding the social component, it consisted of a continuous process of interaction with the HealthCare Solutions team of Link Consulting, throughout the different stages of work. This interaction was made in the form of meetings and a workshop with the members of the team, whenever it was deemed appropriate to explore the viewpoints of the company and assess whether the work was going according to its needs. During the meetings and workshop with the team, an environment of reflection and perspective sharing among the members of the team was always stimulated. As for the technical component, this encompasses all the methods and techniques used in the several steps of the methodology proposed. This focuses more significance in the step of stakeholder analysis, key performance indicators definition and construction of the simulation model.

As a first step, the contextualization of the PTMS was made in order to understand the scope of the non-emergency transport of patients in Portugal, their players and its functioning as an online integrated platform. Thus, and in conjunction with the analysis of some approaches in the literature, it was possible to identify the focus of this work and to clarify its objectives. This allowed designing a methodology that would set the context, characteristics and challenges of this system. As an overview, the proposed methodology was design to:

- Analyze the technical features of PTMS algorithms, through their conceptualization, in order to identify alterations to implement in the algorithms under study;
- Perform a stakeholder analysis in order to identify and categorize the multiple PTMS stakeholders.

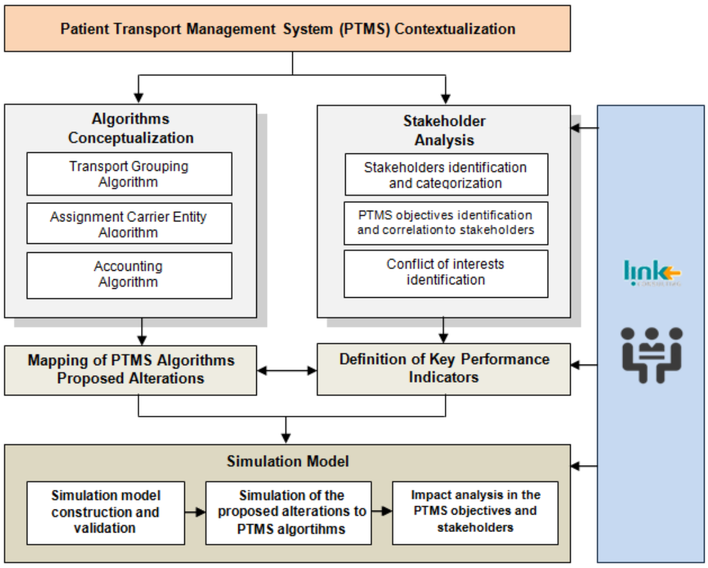


Figure 2 – Methodology proposed set of activities.

This analysis will allow correlating system fundamental objectives to its stakeholders in order to highlight conflicts of interest. The participation of Link Consulting team should be promoted in this analysis through a workshop in order to understand the engagement of each stakeholder and different communication strategies to adopt in respect to each profile identified. The mapping method of stakeholders in an interest and influence matrix was the method chosen for this type of analysis;

- Map PTMS algorithms' alterations to be analyzed. These should represent alternatives to their functional logic and parameter values, and should be validated in a meeting with the company in order to assist their adaptation to its needs;
- Analyze the impact of the proposed alterations on the multiple stakeholder and system objectives in order to assess the feasibility of its implementation and to identify opportunities for improvement in current PTMS algorithms. Therefore, key performance indicators should be set associated to the multiple system objectives and consequently to stakeholders to which they are correlated with. Their suitability should also be discussed and validated with the company. Then, a simulation model should be constructed for analyzing the impact of the proposed algorithm alterations through the performance indicators previously defined. Finally, the simulation of the alterations proposed should be proceeded with. For each analysis, key performance indicators should be collected and then the impact on multiple objectives and system stakeholders assessed.

3.1. Algorithms Conceptualization

The PTMS algorithms are heuristic algorithms since they consist of a set of rules and constraints that are known to ensure the proper functioning of the system, either in transport group formation, carrier entity assignment or transport accounting. Thus, the system does not offer optimal solutions, albeit it should provide those which are sufficiently good from a practical point of view.

The three PTMS algorithms, implemented in *Java* programming language, act sequentially in the system and are programmed to run every 20 minutes in order to allow continuous grouping of new transport requests and accounting of those which were already performed.

As a first step of this work, technical features of PTMS algorithms were analyzed, through their conceptualization, in order to identify alterations to implement in the algorithms under study. It is emphasized however that this study does not intend to optimize PTMS algorithms, but rather look for alternatives that may represent improvements in its operation.

The algorithms' conceptualization was made by designing flow charts since these allow for simple and clear reading of the procedures and represent an easy tool to understand the information flow. Throughout this process it was possible to understand some principles and rules in which the system is based:

- The system allows the permanent binding of some users to carrier entities when justification is provided. These mainly occur in hemodialysis medical services, in order to timely ensure their transport;
- If a user is not bound, the system will assign a carrier entity whose acting area includes the parish of transport origin to his medical services;
- The acting area of a carrier entity is divided into sets of parishes for which it is responsible for. Some parishes or sets of parishes may belong to the acting area of different carrier entities;
- If a transport group has more than a candidate carrier entity, it is assigned to the one with the lowest projected monthly amount in order to ensure equity in transportation services distribution;
- A transport credential can have more than one medical service associated (recurrent credential) and all its medical services should be assigned to the same carrier entity. The system has the principle that a carrier entity responsible for a medical service belonging to a recurrent credential is responsible for the transportation of all the others medical services of the same credential;
- If a new medical service integrates the system, and its transport credential indicates that the user can be transported with other users (multiple transport type), there are several criteria that must be satisfied in order to integrate a transport group formed with medical services for the same day: (1) equal county destination; (2) maximum time interval between services shall be less than the limit stipulated by the RHA; (3) the transport group load plus the medical service shall be less than the capacity of the vehicle;
- The accounting of each medical service transport can be done through two ways: applying an "exit tax" if the medical service associated with the longest path of the transport group does not exceed 20 km. Alternatively, if this limit is exceeded, the accounting is done according to the kilometers traveled by the medical service associated with the longest path of the transport group.

After having identified the main rules and operating principles of PTMS algorithms, it was possible to propose some alterations as deemed relevant to analyze. These will be presented thereupon the analysis of PTMS stakeholders.

3.2. Stakeholder Analysis

3.2.1. PTMS Stakeholders Identification and Categorization

Stakeholder is any individual, group of individuals or entities that are affected by decisions and actions on a system and all those who have power to influence its outcome [14]. As such, PTMS stakeholders were identified and categorized, as shown in Figure 3.

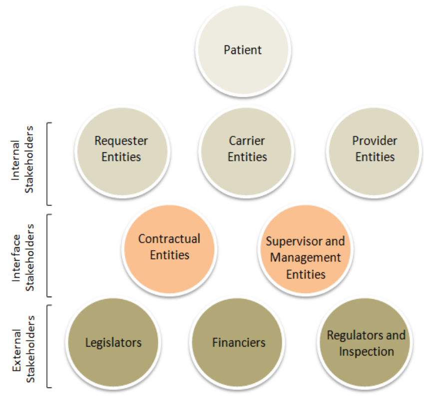


Figure 3 – Internal, interface and external PTMS stakeholders.

First, the system focus was identified as the patient. Although patient action has practically no influence on system operations, any changes to be implemented may affect the system focus, with repercussions not only in the way the transport service itself is provided, but also, in the case of delays, these can lead to non attendance to prescribed clinical acts. Subsequently, internal, interface and external PTMS stakeholders were identified (Table 1). Next, in order to map the PTMS stakeholders in an interest and influence matrix, a workshop was developed with the Link Consulting HealthCare Solutions team. During the workshop, a discussion ideas environment was stimulated, since this method raised some doubts due to the sometimes noticeable duplicity of some PTMS stakeholders' responsibilities in the system. This happened, for instance, when applying the method to the ACSS that plays two roles in PTMS: Supervisor and Management Entity and Financing.

Table 1 - PTMS stakeholders' description and role in the system.

Stakeholders		Description	Role in PTMS
Internal Stakeholders	**Requester Entities**	Primary care and National Network for Integrated Continuous Care (NNICC) units.	▪ Transport prescription at PTMS platform; ▪ Transport service payment (principle of paying prescriber).
Internal Stakeholders	**Carrier Entities**	Fire and *Cruz Vermelha Portuguesa* (CVP) corporations and other public or private carriers since legitimized by *Instituto Nacional de Emergência Médica* (INEM)	▪ Acceptance/rejection of transport groups assigned by PTMS platform. ▪ Completion of the transportation service to Entity Provider, in accordance with transporte credential requirements.
Internal Stakeholders	**Provider Entities**	Physiotherapy and hemodialysis clinics, NNICC, laboratories, among others.	▪ Entries and exits patients registrations of its facilities in PTMS platform; ▪ Provision of services prescribed by the Requester Entity.
Interface Stakeholders	**Contracting Entity**	*Serviços Partilhados do Ministério da Saúde* (SPMS)	▪ Contracts PTMS with Link Consulting, and provides it to the five RHAs and to ACSS.
Interface Stakeholders	**Supervisor and Management Entities**	*Administração Regional de Saúde* (ARS) (RHA)	▪ Monitoring, management and supervision of PTMS platform; ▪ Conflicts resolution ; ▪ Alteration of carrier entities acting areas and bound patients.
Interface Stakeholders	**Supervisor and Management Entities**	*Administração Central dos Serviços de Saúde* (ACSS)	▪ PTMS supervision
External Stakeholders	**Legislators**	Ministries of Health, Finance and Economy; Parliament.	▪ Legislation creation to regulate, normalize and support the proper functioning of PTMS.
External Stakeholders	**Financiers**	ACSS; Population taxes.	▪ PTMS finance.
External Stakeholders	**Regulators and Inspection**	*Entidade Reguladora da Saúde* (ERS) *Inspecção-Geral das Actividades em Saúde* (IGAS)	▪ Regulation and quality assurance of services provided by the multiple parties involved in PTMS; ▪ Audit, inspection, supervision and development of disciplinary action by non-compliance with legal requirements established under the PTMS;

With regard to Regulators and Inspection bodies, IGAS was the only entity considered in this analysis. At the end of the workshop, we came to the following result (Figure 4), with mutual agreement of all elements of the working group.

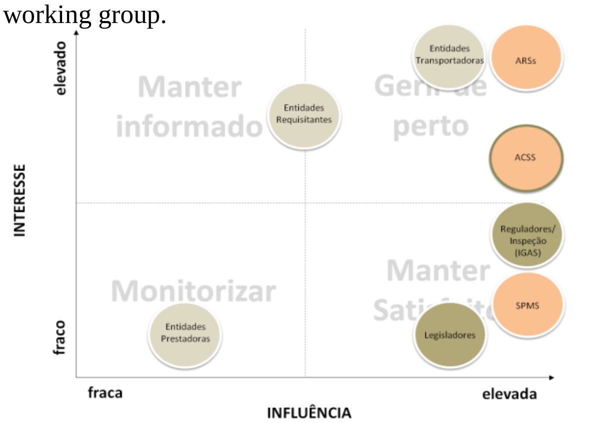


Figure 4 – PTMS stakeholders' interest and influence matrix.

By analyzing the obtained mapping, there are some recommendations on what to expect and what kind of approach should be taken with PTMS stakeholders that can be made. Focusing the analysis on the internal stakeholders, the carrier entities stand out as those with more influence in the system and thereby are the key stakeholders of PTMS. Thus, there must be a good communication with this stakeholder, assuring its active involvement in decision-making processes, and keeping it informed whenever a change is to be made in the system. With regard to requester entities, these also show interest in PTMS however their actions have smaller impact. When accordance is not achieved, it is possible for them to try to create alliances with the most influential stakeholders to gain weight in decision making process. The communication strategy should be similar to the one used with the carrier entities, however, without there being such a pressing need to involve them in an equally detailed way in the decision process. Finally, in relation to provider entities, these are the ones with lower interest and influence in PTMS, since they are only responsible for registering the entry and exit hours of patients in their facilities. Thus, it is not necessary to involve these stakeholders actively in decision making process, or provide them with information in great detail. Yet, it should be noted, that the little interest they have in the system, can lead them to be subject to influence by other stakeholders in order to create majority alliances.

3.2.2. Identification of PTMS Objectives by Stakeholders

After having identified and categorized the multiple PTMS stakeholders, the fundamental and means objectives of this system were also determined (Figure 5). Subsequently, relationships between PTMS fundamental objectives and the interests of its main stakeholders were recognized (Table 2). The objectives identified were discussed and validated at a meeting with the Link Consulting.

Table 2 – PTMS fundamental objectives and main associated stakeholders.

PTMS fundamental objectives	Main associated stakeholders
Minimization of user inconvenience	Patients, requester entities, and supervisor and management entities
Minimization of total transportation costs	Requester entities, and supervisor and management entities
Maximization of available resources use (vehicles, medical/nursing teams, diagnostic equipments, …)	Carrier entities, provider entities and supervisor and management entities
Equitable distribution of transport groups by carrier entities	Carrier entities and supervisor and management entities

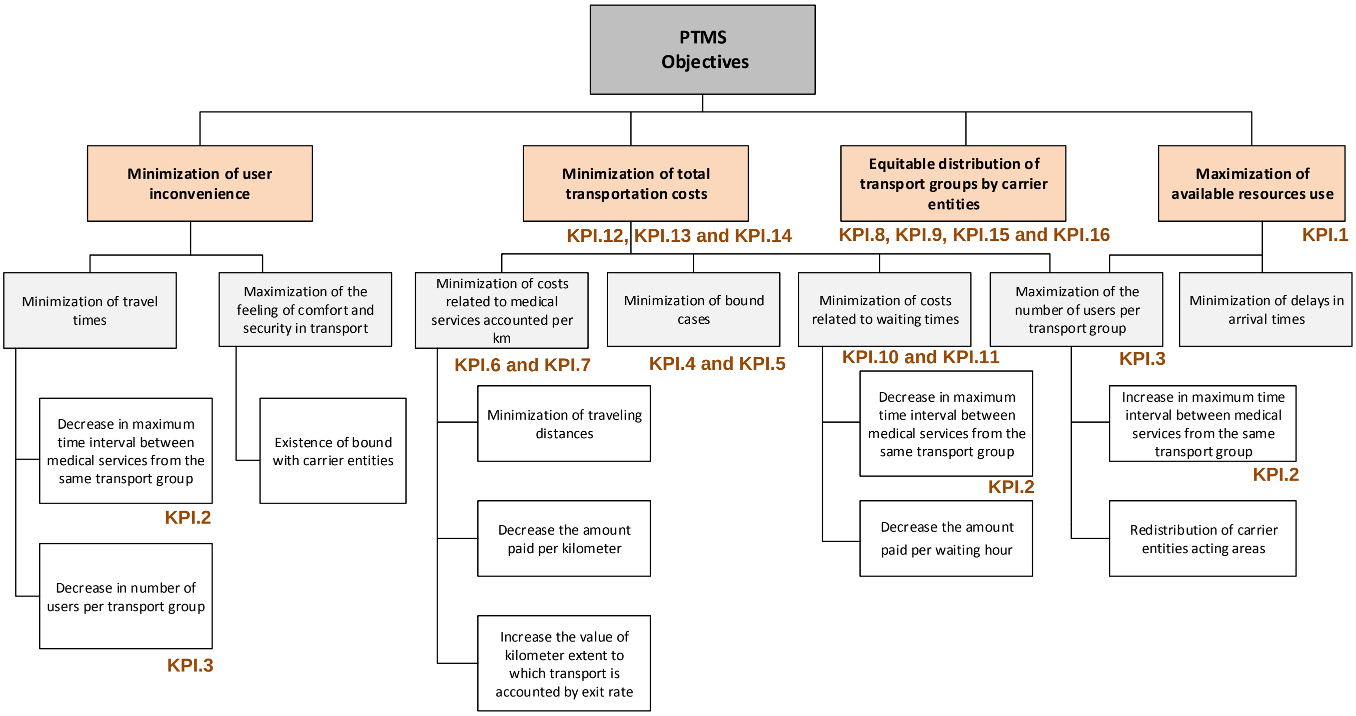


Figure 5 – Fundamental and means PTMS objectives and associated key performance indicators.

3.2.3. Conflict Identification of PTMS Objectives and Stakeholders

By analyzing Figure 5, it is possible to identify conflicts between the means objectives of some PTMS fundamental objectives. One way to minimize users inconvenience is minimizing transport travel times. This is achieved by reducing the maximum time interval between medical services of the same transport group and the number of users per transport group. However, these instances are in conflict with the objective of maximizing the use of available resources that, in the case of vehicles, is achieved by maximizing the number of users per transport group. Addiotionally, in order to minimize user inconvenience conditions for comfort and sense of security should be created wherever possible in the transport service. This can be achieved, for instance, by creating a bond between the user and a carrier entity, as guarantee of commitment to carrying out the transport by it. However, that represents an increment in costs to the system, which conflicts with the objective of minimizing total costs. Again, the delicate balance between minimizing user inconvenience and transport costs becomes evident, as it does repeatedly in transportation systems found in the literature. Therefore a compromise must be found, through some concessions from both parties, in order to satisfy stakeholders whose interest is to minimize user inconvenience and stakeholders whose biggest concern lies in minimizing transportation costs.

3.3. Definition of Key Performance Indicators

After identifying the PTMS fundamental objectives, key performance indicators were defined (Table 3) in order to make the impact produced by proposed alterations measurable. Thus, through the greater or smaller degree of success achieved for each of the objectives and associated stakeholders, it becomes possible to analyze the adequacy and viability of the proposed alterations to PTMS algorithms. Only key performance indicators whose values were possible to withdraw through the database used were defined. Thus, although not all the fundamental objectives have direct associated indicators however this does not preclude an overall analysis of the impact of the alterations proposed.

Table 3 – Key Performance Indicators defined

Key Performance Indicators	
KPI.1	Number of multiple transport groups
KPI.2	Average maximum time interval between medical services / Transport Group (minutes)
KPI.3	Average number of medical services / Transport Group
KPI.4	Costs associated with bound patients within their residence area
KPI.5	Costs associated with bound patients outside their residence area
KPI.6	Total cost associated with medical services accounted per km
KPI.7	Total cost associated with benefits accounted per exit tax
KPI.8	Carrier entities percentage that increased the average maximum distances traveled
KPI.9	Carriers entities percentage that decreased the average maximum distances traveled
KPI.10	Total costs associated with waiting times
KPI.11	Average waiting time / Transport Group (hours)
KPI.12	*Agrupamentos de Centros de Saúde* (ACeS) percentage that increased expenses associated with transport
KPI.13	ACeS percentage that decreased expenses associated with transport
KPI.14	Total costs associated with users transport
KPI.15	Carriers entities percentage that increased revenue associated with users transport
KPI.16	Carriers entities percentage that decreased revenue associated with users transport

3.4. Mapping of PTMS Algorithms Proposed Alterations

After conceptualization of PTMS algorithms and analysis of its stakeholders, alterations to algorithms whose impact on the system where to be analyzed, were mapped. These alterations were based on the search for alternatives for functional logic and value of parameters of the system algorithms. They can be found in the following Table 4.

Table 4 – PTMS algorithms proposed alterations.

	In operation	Alterations to simulate
Alterations in functional logic of transports group formation	Maximum time interval between medical services from the same transport group	▪ Within the county: 1h ▪ Outside the county: ▪ 1h (< 100km) ▪ 2h (≥ 100km)
	Destinations: ▪ Within the county: 1h ▪ Outside the county: ▪ 2h (< 100km) ▪ 4h (≥ 100km)	▪ Within the county: 1h ▪ Outside the county: ▪ 1h (< 50km) ▪ 2h (≥ 50km)
	Grouping users with the same **county** destination	Grouping users with the same **parish** destination
		Grouping users with the same **provider entity**
Alterations in functional logic of carrier entity assignment and acting areas distribution	It is possible to bound users to carrier entities is possible and they are priority in the formation of transport groups	Not possible to bound users
		Possibility to bound users but only with carriers that act on their residence area
	Assignment of all medical services from a recurrent credential to the same carrier entity	Equitable distribution of the medical services from a recurrent credential by the candidates carriers
	Users belonging to different parish sets of the acting area of same carrier cannot be grouped together	Users belonging to the acting area of same carrier can be grouped together independently of the parish sets
Alterations of accounting parameters	Maximum amount paid by the NHS per kilometer = € 0.51	Price per kilometer = 0.52 €
	Exit tax value = 7.5 €	Exit tax value = 10 €
	Accounting for exit tax up to 20 km	Accounting for exit tax up to 25 km

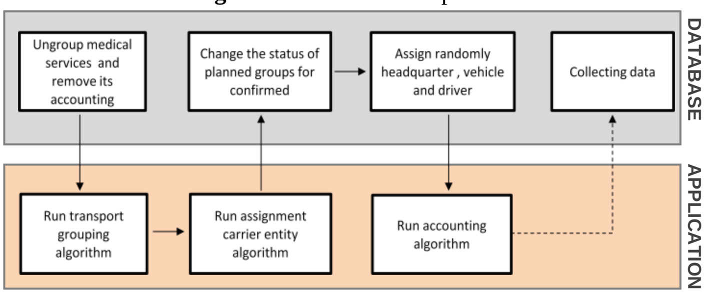
3.5. Simulation Model Construction and Validation

In order to understand the impact of the proposed alterations on multiple objectives and stakeholders of the system, a simulation model that allowed the simulation and thus prediction of PTMS behavior when subjected to changing conditions was built. To this end, the PTMS application supported by Link Consulting was used, in order to ensure the greatest possible reliability of the simulation results. Therefore, we used an application server to run the PTMS application itself and to access a database created by the Link Consulting company, to be subjected to the defined simulation scenarios. In respect to the sample data generated for simulation purposes, and used in this work, this is constituted by 28538 medical services, 94.3% of which correspond to multiple transport type. Bound users represent 8.3% of those medical services, 6.7% of which are made out of users bound within the residence area and another 1.6% of users bound outside their residence area. As for recurring medical services, these represent 98.6% of medical services, 45.39% of which are for dialysis services. After each simulation, the key performance indicators were collected, using SQL Developer, in which were developed queries in PL-SQL language for that purpose.

3.5.1. Simulation Procedures

The proposed alterations represented different degrees of complexity. While some consisted of a simple alteration in the value of a parameter in the database (single act by SQL Developer software), others, more structural, were made through alterations directly in *Java* code in which the algorithms are implemented. Regardless of the alterations made, the process of simulation was always composed of the same steps (Figure 6).

Figure 6 – Simulation steps.



At this stage of the methodology, 15 simulations were undertaken, each lasting about six hours, and about 50 queries in PL-SQL language were built, in order to remove the values obtained for each key performance indicator.

3.5.2. Model Validation

The constructed model is based on certain assumptions that differ from the actual PTMS application such as:

- The tacit acceptance by the carriers of all transport groups assigned to them (which does not necessarily correspond to reality, occurring sometimes cases of rejection);

- The random assignment of headquarter, vehicle and driver to accepted groups, which can lead to inaccuracies in respect of transport costs, since the number of kilometers covered starts from the headquarters site. However, it was found that the number of cases of carriers with more than one headquarter was much reduced, being not sufficient to invalidate the proposed analysis;
- The inexistence of cancellations. The model assumes that all services completed the whole transportation process.

Still, the fact of having used the PTMS application itself for performing the simulations significantly minimizes possible deviations than what would have happened in the real case. It should be noted also that throughout the simulation process, there was a joint assessment with Link Consulting team on the used model and procedures and a continuous verification of the consistency of the obtained results.

4. Results

Before proceeding with planned simulations, reference values were obtained by conducting an initial simulation without any alterations in PTMS algorithms (S0). Initially, individual alterations were simulated over the same sample (S1-S11), i.e. each simulation represented a single alteration in an algorithm. Subsequently, after analysis of the obtained results, four simulations were designed and performed (A, B, C and D), each representing more than one algorithm alteration.

These allowed system behavior analysis when subjected to a series of alterations that significantly changed its current algorithms' operating logic. The results of each individual simulation can be found in the global table presented below (Table 5). For each key performance indicator, the variation was calculated as a percentage relative to baseline values. Thus, it was possible to analyze which simulations have shown greater impact on the PTMS objectives and stakeholders.

In order to highlight some values and to enable further analysis, it was used the following color code:

Yellow: to highlight values that reveal greater impact on the objective of "minimization of user inconvenience"; **Blue**: to highlight values that reveal greater impact on the objective regarding "minimization of total transportation costs"; **Green**: to highlight values that reveal greater impact on the objective for "equitable distribution of transport groups by carrier entities"; **Red**: to highlight values that reveal greater impact on the objective of "maximization of available resources use".

Given the results of individual simulations, the combined simulation of some alterations to the model in order to build alternative scenarios for the current PTMS algorithms' functioning was considered. These simulations have been planned with the concern of mitigate conflicts of interest, which was evidenced in previous results, combining changes that tried to meet objectives associated with different PTMS stakeholders. The planned simulations, some more radical than others, and the alterations included were as follows: A (S4+S9+S1); B (S4+S9+S11+S1); C (S6+S4+S11+S9) and D (S6+S11+S9). The results of these simulations are systematized in Table 6. To highlight some values, the same color code as in Table 5 was used.

Table 5 - Percentage variations of key performance indicators of each individual simulation relative to reference values.

Simulations		Transport Groups				Costs						Equity					
		(KPI.1) Number of multiple transport groups	(KPI.2) I Average maximum time interval between medical services / Transport Group (minutes)	(KPI.3) Average number of medical services / Transport Group	(KPI.11) T Average waiting time / Transport Group (hours)	(KPI.14) Total	(KPI.6) Medical services accounted by kilometers	(KPI.7) Medical services accounted by exit tax	(KPI.4) Bound patients within their residence area	(KPI.5) Bound patients outside their residence area	(KPI.10) Waiting times	(KPI.8) % Carrier entities that increased the average maximum distances traveled	(KPI.9) % Carriers entities that decreased the average maximum distances traveled	(KPI.12) % ACeS's that increased expenses associated with transport	(KPI.13) % ACeS's that decreased expenses associated with transport	(KPI.15) % Carriers entities that increased revenue associated with users transport	(KPI.16) % Carriers entities that decreased revenue associated with users transport
S0	Reference values	11952	26,74	2,25	3,37	597170	582545	14625	66719	20973	131730	-	-	-	-	-	-
S1	Price km = € 0.52	-	-	-	-	+ 1,48	+ 1,51	0,00	+ 1,42	+ 1,39	- 0,01	-	-	100,00	0,00	100,00	0,00
S2	Exit fee = 10€	-	-	-	-	+ 0,82	0,00	+ 33,33	+ 0,09	0,00	0,00	-	-	100,00	0,00	60,22	0,00
S3	Accounting by exit fee until 25km	-	-	-	-	- 0,30	- 0,59	+ 11,28	0,93	0,00	- 3,37	-	-	0,00	100,00	8,60	22,58
S4	No bound cases	- 4,79	+ 4,10	+ 5,03	+ 0,70	- 3,13	- 2,93	- 11,23	- 100,00	- 100,00	- 3,09	26,88	32,26	0,00	100,00	32,58	34,83
S5	Bound cases only with carriers that act on their residence area	- 4,19	+ 3,22	+ 4,38	+ 0,72	- 2,44	- 2,23	- 10,72	+ 17,20	- 99,37	- 2,54	31,18	27,96	0,00	100,00	32,22	35,56
S6	Grouping users with the same provider entity	+ 9,30	- 3,87	- 8,51	- 0,51	+ 5,69	+ 5,71	+ 4,87	+ 10,53	+ 9,20	+ 7,57	26,88	39,78	100,00	0,00	50,00	22,22
S7	Grouping users with the same parish destination	+ 7,51	- 0,50	- 6,99	+ 0,42	+ 5,07	+ 5,09	+ 4,51	+ 10,41	+ 9,02	+ 7,27	26,88	37,63	83,33	16,67	46,67	22,22
S8	Users belonging to the acting area of same carrier can be grouped together independently of the parish sets	- 3,24	+ 3,58	+ 3,35	+ 1,51	- 0,91	- 0,66	- 10,72	+ 0,28	- 1,51	- 0,52	26,88	22,58	16,67	66,67	27,78	27,78
S9	Maximum time interval between medical services from the same transport group: 1h until 100km and 2h after 100km	- 0,72	- 13,31	+ 0,72	- 0,73	- 0,26	+ 0,01	- 10,97	+ 0,22	- 1,35	- 1,31	20,43	31,18	50,00	50,00	32,22	31,11
S10	Maximum time interval between medical services from the same transport group: 1h until 50km and 2h after 50km	- 0,74	-12,80	+ 0,74	- 0,70	- 0,30	- 0,04	- 10,56	+ 0,44	- 1,51	- 1,22	20,43	31,18	50,00	33,33	33,33	26,67
S11	Equitable distribution of the medical services from a recurrent credential by the candidates carriers	- 14,39	+ 7,02	+ 16,81	+ 2,14	- 4,41	- 3,80	- 21,85	- 4,78	+ 0,78	- 9,80	38,71	24,73	0,00	100,00	29,03	31,11

Table 5 - Percentage variations of key performance indicators of each combined simulation relative to reference values.

Simulations	Transport Groups				Costs						Equity					
	(KPI.1) Number of multiple transport groups	**(KPI.2)** I Average maximum time interval between medical services / Transport Group (minutes)	**(KPI.3)** Average number of medical services / Transport Group	**(KPI.11)** T Average waiting time / Transport Group (hours)	**(KPI.14)** Total	**(KPI.6)** Medical services accounted by kilometers	**(KPI.7)** Medical services accounted by exit tax	**(KPI.4)** Bound patients within their residence area	**(KPI.5)** Bound patients outside their residence area	**(KPI.10)** Waiting times	**(KPI.8)** % Carrier entities that increased the average maximum distances traveled	**(KPI.9)** % Carriers entities that decreased the average maximum distances traveled	**(KPI.12) %** ACeS's that increased expenses associated with transport	**(KPI.13) %** ACeS's that decreased expenses associated with transport	**(KPI.15)** % Carriers entities that increased revenue associated with users transport	**(KPI.16)** % Carriers entities that decreased revenue associated with users transport
S0	11952	26,74	2,25	3,37	597170	582545	14625	66719	20973	131730	-	-	-	-	-	-
A	-10,19	-10,29	+11,35	-0,94	-1,85	-1,25	-25,90	-100,00	-100,00	-9,71	30,11	31,18	33,33	66,67	65,17	34,83
B	-14,27	-7,95	+16,65	-1,00	-5,48	-4,77	-33,69	-100,00	-100,00	-13,80	38,71	29,03	33,33	66,67	61,96	38,04
C	-5,19	-13,95	+5,47	-2,25	-2,12	-1,91	-10,21	-100,00	-100,00	-7,81	36,56	40,86	50,00	50,00	47,31	36,56
D	-0,64	-16,40	+0,65	-0,84	+1,74	+2,05	-10,51	+6,12	+0,53	-1,66	40,22	33,70	83,33	16,67	52,17	29,35

4. Discussion

Upon collecting results from the simulation, it was possible to analyze the impact of individual and combined alterations on multiple PTMS objectives and their correlated stakeholders. This analysis allowed the confirmation of conflicts between system objectives and, consequently, between the interests of its multiple stakeholders for the vast majority of the alterations proposed. However, those simulations which proceeded a change in maximum time intervals between medical services from the same transport group proved to be deserving of special attention. These alterations enabled a better reorganization of transport groups without impacting on costs, bringing medical services with closer schedules together, which is undeniably advantageous from both the users and the carriers. As such, adjusting the maximum time interval should be considered as an improvement to implement the system. To finalize, some considerations about the methodology developed in this work can be made.

In respect to its limitations, specifically in the step for defining key performance indicators, some of these were defined as average values (KPI.2, KPI.3 and KPI.11). However, to take more stringent conclusions about system behavior, it could be pertinent to conduct a statistical analysis on these values that allowed more definitive proof of their suitability as indicators. Another limitation of this methodology relates to the fact that a sample of medical services was used, during the simulation process which does not aid in perceiving the impact of seasonality and other possible behavioral patterns of the PTMS' real functioning.

On the other hand, this methodology presents a few main advantages such as a differentiated approach to the study of functional alternatives for algorithms of a system. This is the case since the impact analysis is focused on system objectives and correlated stakeholders, as opposed to those, found in literature, that intended to implement optimization approaches. Furthermore, by similarly promoting constant interaction with the company that this analysis aims to support the present methodology, through a socio-technical approach, leads to greater alignment of the work in progress with the needs identified by it, allowing the analysis to be assessed and validated consistently.

Concluding, this study allowed to develop and implement a methodology capable of analyzing alterations to PTMS algorithms, focusing on the impact on their multiple stakeholders Thus, it was possible to generate information capable of supporting Link Consulting in PTMS improving opportunities analysis and provide it with some communication strategies adjusted to the different profiles of system stakeholders. Thus, it is considered that the objectives proposed at the beginning of this work have been met. Still, we recognize the enormous potential of different alternatives, reflections and new procedures to test the PTMS and it is hoped that this work constitutes a good basis for it.

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