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Research Article

A systematized approach for reduction of medical appointment waiting list

Bruno S. Gonçalves[a,b*], Elisa Vieira[a], Rui M. Lima[a], José Dinis-Carvalho[a]**

[a]Universidade do Minho, Escola de Engenharia, Centro Algoritmi, Departamento de Produção e Sistemas, Guimarães, Portugal
[b]Departamento de Engenharia Mecânica, Escola Superior de Tecnologia e Gestão, Instituto Politécnico de Leiria, Leiria, Portugal
*bruno.goncalves@ipleiria.pt, **rml@dps.uminho.pt

Abstract

Paper aims: This work aims to develop a systematized approach for the reduction of medical appointment waiting lists, proposing an optimization decision-making model followed by continuous people engagement towards a systematic approach for waiting list problem-solving.

Originality: There are several studies related to waiting lists in healthcare contexts, however, the present study presents an innovative approach for waiting list problem-solving by proposing prescriptive decision-making models followed by continuous improvement and people engagement.

Research method: A research approach with the following phases was developed: system analysis, problem quantification, and development of an optimization model. After these phases, the model was applied, and the results were analysed, as contributions to a systematized model.

Main findings: The model was applied to the screening waiting list for orthopaedics appointments followed by the fundamental involvement of medical doctors, which made it possible to implement the optimal solution generated by the model, resulting in a reduction of 90% by 56 days in waiting time for the screening process.

Implications for theory and practice: This model contributes for theory and for practice as a way to deal with different scenarios for waiting list reduction in the upcoming days during and after the pandemic.

Keywords

Hospital operations management. Lean healthcare. Capacity planning. Waiting list. Elective patients.

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1. Introduction

The existence of waiting lists for elective procedures is a common issue in the health services in several countries (Almomani & AlSarheed, 2016; Comans et al., 2017), representing a difficulty to comply with the expected Guaranteed Maximum Response Time (GMRT). Waiting lists are viewed as necessary to avoid idle time of valuable medical resources, but are also a problem as they are usually much longer than necessary due to the lack of capacity to deal with the demand (Worthington, 1991). The waiting list creates a late response to the patient's needs that can lead to a worsening of their health status. There are two types of waiting times for patients, the waiting time spent in the hospital (Mandahawi et al., 2017) and the waiting time for an appointment date (Lin, 2015; Chen & Juan 2013), classified as the access time or indirect waiting time.

As an example, the relationship between the waiting time and the patient's clinical status was studied (Chen et al., 2008; Simunovic et al., 2010) in some orthopaedic pathologies. Another recent study analysed a way to reduce the waiting time for an ambulance in emergency medical services (Yu et al., 2020). Several other authors developed during the last decades different approaches to deal with healthcare waiting lists problems.

Testi et al. (2007) developed a three-phase hierarchical approach for the weekly scheduling of operating rooms, aiming an integrated way of facing surgical activity planning in order to improve overall operating theatre efficiency in terms of overtime and throughput as well as waiting list reduction. Smith & Hadorn (2002) developed a priority criteria model for reliably assess patients urgency level and reducing waiting lists for medical support. Comas et al. (2008) presented a discrete-event simulation model for use in decision-making in the context of waiting list management strategies in which a comparison between a waiting list prioritization system and a routinely used first-in, first-out (FIFO), is carried out. (Mangan et al., 1992) studied the phenomenon of medical appointments cancellation and its impacts on the services waiting list. Vissers et al. (2001) tackled the waiting lists phenomena in a high-level framework. A reference framework for waiting list management is described, distinguishing different levels of planning in healthcare demonstrating that each level contributes to the existence of waiting lists through managerial decision making.

There are several studies related to the phenomenon of waiting list in healthcare contexts, however the present study presents an innovative approach for waiting list problem-solving by proposing prescriptive decision-making models with continuous improvement cycles and people engagement towards a systematic approach for waiting list problem-solving.

This study addresses the access time of elective patients for the first appointment of medical specialties, coming from primary healthcare services and was developed in collaboration with a Portuguese public hospital. The study started with an improvement project in the orthopaedic specialty having been interrupted by due to Covid 19 pandemic. However, this document presents data collected before and during the pandemic. In Portugal, due to the epidemic of the new coronavirus, SARS-CoV-2, among other restrictions, it was recommended by health authorities that the use of health services should be reduced to the essential. Thus, primary healthcare services did not send so many patients for hospital appointments, which triggered, in the case of elective patients, a reduction in the waiting list for first medical appointment, however the waiting times are still high.

Being recognized the difficulty of managing the waiting lists in an empirical way (van Bussel et al., 2018; Elkhuizen et al., 2007), this article aims developing a systematized approach for reduction of medical appointment waiting list. This approach proposes an optimization method for determining the minimum number of hours * doctor needed in a period of time, to reduce and maintain the waiting list for first medical appointment within predefined dynamic limits. After determining that limit, the hospital may consider usual capacity planning strategies to accomplish the reduction of the waiting list: extra-hours, acquiring extra resources, subcontracting the extra capacity.

Such a model should be designed to be effective and easy to use by health professionals, providing powerful outcomes to help in the resource capacity allocation decision process.

The main gap relies on the lack of a systematized approach for problem solving with a well-defined step-by-step process that allows each medical service to, locally and individually, perform custom analyses for specific problem solving. This work provides a systematized approach that guides the medical services in structuring and defining the problem and then provides tools for the problem solving. The approach allows for custom problem definition and custom problem solving which is of paramount importance as each medical service has its own characteristics, work method and resources. This approach greatly increases medical services capability and flexibility on custom problem analyses and solving.

The paper follows with a literature review, which provides an overview of different approaches to the problem (section 2); section 3 presents a brief problem description, the research method applied, and the proposed optimization model and the application context are presented; this is followed by the application of the model to an hospital real problem (section 4); finally section 5 presents the discussion of the results, followed by the main concluding remarks.

2. Literature review

With the main objective of improving the services provided, promoting an increase in added value to the patient (Miao et al., 2020), there are several studies in the literature that aim to reduce the waiting time in different health services. Literature reviews show the adoption of production system techniques adapted to health services, indicating a growing focus on operations management (Keskinocak & Savva, 2019). In particular, using the Lean production system, several initiatives have been introduced in health services, with an emphasis on hospital areas such as the emergency department and operating room (Lima et al., 2021; Costa & Godinho Filho, 2016). Although these studies demonstrate the good results of lean initiatives promoted in various health sectors, the importance of involving health professionals, including physicians, is emphasized as a fundamental factor for their long-term sustainability (Leite et al., 2020; Fournier et al., 2021).

Likewise, also the use of statistical mathematical models and algorithms to analyse and quantify the relevant aspects in a health care context, typically with the aim of improving or optimizing performance and helping in decision making, have been adopted in health services (Priyan, 2017). Namely, in the surgical planning and scheduling process by developing an optimization model for effective scheduling, contemplating the involvement of health professionals for an easier implementation (Visintin et al., 2017). In the same way on the management of queues for diagnostic exams demonstrating the efficiency of new alternatives to the models in force through numerical experiments (Geng et al., 2017). In a broader approach, regarding to problems involving capacity planning in hospitals, there are many examples of how operations research models can be used to provide important information about operational strategies in health services (Green, 2005; Raymond et al., 2016; Frost, 1980; Lodge & Bamford, 2007; Elwyn et al., 1996; Neby et al., 2015; Escobar et al., 2009; Cipriano et al., 2008; Tatham et al., 2012).

Concerned with political approaches, given the importance of reducing waiting times to promote faster access to elective health care by the population, several measures have been promoted in several OECD countries (Siciliani et al., 2014). In Portugal, measures such as the introduction of an integrated computer system for the National Health System (NHS), the free movement of patients within the NHS, the introduction of GMRT and the creation of vouchers for patients who exceed this waiting times, demonstrated positive results (Barros et al., 2011; Siciliani et al., 2014).

In a similar approach as to this study, van Bussel et al. (2018) make a great contribution on analysing real outpatient demand, supply and access time. The authors present a 6-step model to gain insights for guidance in redesigning the access to a medical appointment system and a better match between demand, supply and access time. Differently to such approach, this study does not include follow-up medical appointments, which, although important, do not interfere with the legal time constraints imposed by the ministry and so are not considered in the presented analysis approach.

Likewise Elkhuizen et al. (2007) used a waiting list analysis model to determine the capacity needed to meet the demand for patients and developed a simulation model that could handle daily variations in demand and capacity schedules. The authors present the results for the need to eliminate delays and the ability to maintain access time within 2 weeks. Both models were applied in two outpatient departments and provided results very close to those observed in the implementation. Woodhouse (2006) developed a opt-in appointment system to inform the waiting list management. By doing so the attendance at first appointments was significantly increased and waiting times were significantly reduced. Spratt & Kozan (2016) tackle the waiting list management problem by generating master surgical schedules that adhere to staff and equipment restrictions whilst ensuring patients are treated in a timely manner. Stochastic surgical durations were considered to produce more robust schedules and reduce unexpected overtime. Regarding the same clinical area, Al-Hakim (2006) developed a model to manage waiting lists for surgery interventions with three specific objectives: unifying the waiting lists, reduce the unexpected deviation of planned activities and deliver an effective support system for decisions-making. In Bowers (2011), the behaviour of waiting list management is simulated in which a model of waiting list management is developed that includes an explicit measure of priority associated with the patient's wait compared to specified targets. Briggs et al. (2011) developed a multifaceted approach to wait list management including audit, direct lines of communication between clinical and administrative staff, resources planning and outsourcing and others.

While this literature review has not the objective of being complete, a summary allow to identify an increasing interest in the application of operations management (Costa & Godinho Filho, 2016; Lima et al., 2021) methods and approaches to several health services with a special focus in increasing the value added to the patient (Miao et al., 2020), involving as much as possible the health professionals (Fournier et al., 2021; Leite et al., 2020) in the process of finding the best solutions. Thus, it was possible to identify the following references related to operations management approaches and hospital areas:

- Operations management approaches: queue management (Geng et al., 2017); statistical modelling (Priyan, 2017); operations research (Bowerman et al., 2007; Cipriano et al., 2008; Elwyn et al., 1996; Escobar et al., 2009; Frost, 1980; Green, 2005; Neby et al., 2015; Raymond et al., 2016; Tatham et al., 2012); demand (outpatient) management (van Bussel et al., 2018); capacity planning (Elkhuizen et al., 2007); master production scheduling (Spratt & Kozan, 2016); priority management (Bowers, 2011).

Hospital areas: Emergency department; surgical department (Visintin et al., 2017; Spratt & Kozan, 2016; Al-Hakim, 2006); diagnostic exams (Geng et al., 2017); outpatient consultation (Siciliani et al., 2014; van Bussel et al., 2018; Elkhuizen et al., 2007; Woodhouse, 2006; Bowers, 2011; Briggs et al., 2011).

The objective of the current work is to encompass high degrees of flexibility when dealing with the most common constraints regarding the dynamic levels of waiting list, demand and capacity needed. Fully autonomous or manual handling modes should be provided so the medical teams or hospital administration may use the one that best fits the context under analysis. A systematic modelling and analysis approach is aimed so that the model can be transversally used across all types of medical specialties.

3. Methods

This section describes in detail the methodological approach, the waiting list for medical appointments problem, followed by the approach developed to tackle that problem, based on an optimization model. In the context of the developed work the concept of waiting list represents the number of patients waiting for a healthcare service.

3.1. Systematic approach

This study addresses capacity management for first medical appointments, in the elective services of a Portuguese hospital. Figure 1 shows the main steps followed on the development of the study.

Thus, to obtain accurate insights for the research, a mixed-methods approach was performed to collect both quantitative and qualitative data. Since part of this study was developed in 2019 and was extended in time during the covid 19 pandemic, data collection and analysis were performed at different times. So, in 2019, it was made a careful analysis of the data referent to 2018, on access to orthopaedics appointments. Namely, data relating to the number of schedules, number of first orthopaedics appointments, number of referrals for first orthopaedics appointments and waiting list were analysed and processed. Likewise, to understand the current state of the situation due to the pandemic, data on the number of referrals received by the hospital in 2019 and 2020 for the first appointment of orthopaedics and the waiting list in April 2021 were analysed and processed. Likewise, several interactions were promoted with orthopaedists and other health professionals to the characterization of the problem and an in-depth understanding of its perceptions. For a better contextualization of the problem, current legislation was also consulted regarding GMRT.

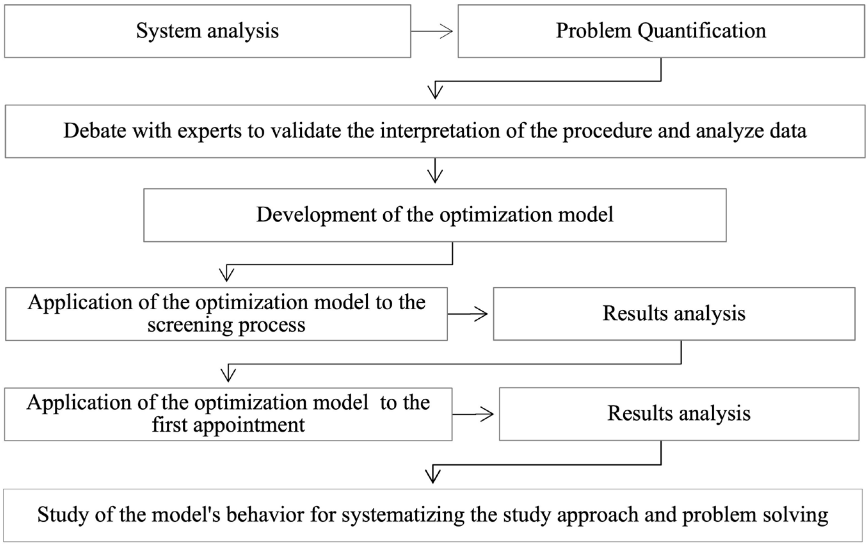

Figure 1. Methodological approach.

3.2. Problem description

For a patient to have access to the hospital's outpatient service, it is necessary that MD from primary healthcare services, hospital inpatient services or emergency services perform a patient referral to the service. This study focuses on patients from primary healthcare services. Thus, for these patients, the access to an orthopaedics appointment begins with the referral of the general clinical doctors (also known as "family doctors" in Portugal).

The referral will provide the orthopaedist with essential basic information for the screening process, such as the patient's medical history, and will also contain details that allow the classification of the patient's degree of urgency. In the medical screening process, MD should prioritize referrals to establish an orderly place on the waiting list, according to the patient's clinical status, to schedule the appointment. Likewise, the doctor has the possibility to refuse referral if he considers that the appointment is not justified, or to return the referral to family doctors to review the clinical process of the patient (for example, due to lack of clinical information or due to lack of exams). If the request is accepted, then a priority is assigned. If the request is discarded, then it may be completely discarded being then removed from the system (and waiting list) or it may be returned to family doctors, to obtain more information, and the request remains in the system increasing the waiting time continuously until a response. Figure 2 illustrates how the waiting times for the different processes, screening, and first medical appointment, are determined.

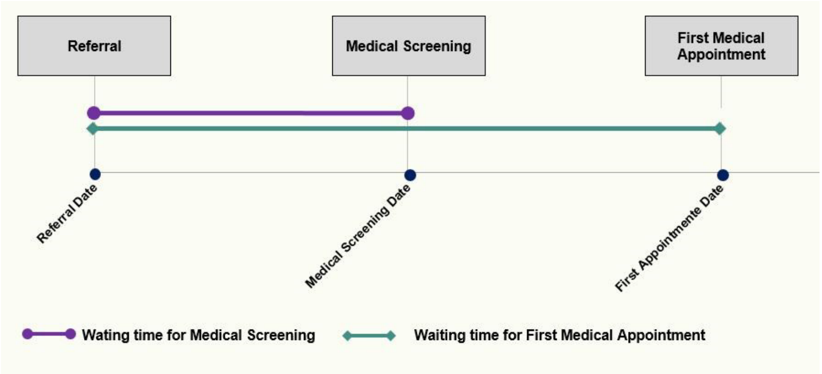

Figure 2. Measurement of the waiting time for screening process and first medical appointment.

The waiting time for the first appointment and for medical screening represents the difference between the effective date in which each process takes place and the arrival date of the referral. The waiting time for the first appointment is counted from the patient referral arrival, however the patient is not included on the waiting list for first appointment until the screening process is completed (although waiting time is still counting). Thus, it is considered the existence of two waiting lists, the waiting list for screening and the waiting list for the first appointment.

These referrals are widely monitored by health authorities, especially regarding waiting times. Based on the GMRT imposed by law, the screening process should take place within a limit of five days and the first appointment should be provided in 30 days for very urgent requests, 60 days for urgent requests and 120 days for normal requests. However, in the hospital under study, the waiting times are far above these reference values, representing a great concern for the hospital administration because, in addition to late patient care, they are associated with financial penalties.

Thus, taking into consideration the variations in demand as well as in available capacity, the management of waiting lists and consequently access times becomes complex (Elkhuizen et al., 2007). Thus, understanding how capacity and demand affect the waiting list is essential to guarantee a certain level of service, with regard to access time (van Bussel et al., 2018) .

In the same way, other constraints like the efficiency of the resources, the days that the speciality operates, and the existing waiting list make the reduction and maintenance of the waiting list a problem difficult to be solved empirically. Thus, this study aims responding to the following research question:

(1) What optimization model allows the definition of the necessary capacity to comply with the pre-defined and dynamic levels of the waiting list in an effective, easy to use and accessible approach to health professionals so that can be systematically applied to all medical specialties?

3.3. Solution approach

With main objective to provide a solid support tool for decision making, assessing the needed capacity, translated into hours * doctor per day, an optimization model was developed. This model allows to manage the waiting list for medical screening and first appointment to promote the reduction of waiting time. The optimization model presented next was applied to the access waiting lists of orthopaedics speciality in real context. Before pandemic, considering the high demand for orthopaedics elective services and in parallel with a continuous improvement project under development in the hospital in the orthopaedics service, the optimization model was applied to the orthopaedics screening waiting list. Subsequently, considering the effects of the pandemic, it was refined and prepared to be applied to the waiting list for the first medical appointment.

3.3.1. Formulation of the model

Following the presented approach (Figure 1), after analysing the system that stores the accesses to the first appointments and quantifying the problem through the analysis of the collected data, it was possible to quantify and identify the variables and constraints of the problem. Therefore, to validate the interpretation of the procedure and analysed data, a debate with orthopaedics doctors was promoted, which allowed the development of the present optimization model.

Thus, to support the decisions on how to manage the waiting list for the screening process and the first medical appointment, the optimization model was developed to achieve the optimal solution for the minimum number of hours required for a time period of 52 weeks. This integer linear programming model uses OpenSolver in the Excel VBA add-in, which extends Excel's built-in Solver capabilities. The option for using the Microsoft Excel is justified due to its great dissemination across hospital computers, meaning that no extra software is needed which also represents no investment needed. By being well disseminated across the hospital facilities it also enables the transferability, transversality and systematicity of the model and approach though all medical specialities.

The model is defined according to mathematical notation of the parameters, decision variables, objective function and constraints in order to allow an adequate conceptual modelling of the problem.

Indices

i identifies the week, $\forall\ i \in \{1,52\}$.

Parameters

C represents an additional (higher) cost per extra hour.
LI represents the current waiting list.
$\mathrm{LP_i}$ represents the expected (forecasted) waiting list for week i.
$\mathrm{LMAX_i}$ represents the desired maximum waiting list for week i.
$\mathrm{LMIN_i}$ represents the minimum waiting list for week i.
$\mathrm{HMAX_i}$ represents the maximum number of hours * doctor per day for week i.
$\mathrm{HMINV_i}$ represents the minimum number of hours * doctor per day for week i.
$\mathrm{EHMAX_i}$ represents the maximum number of extra hours * doctor per day for week i.
$\mathrm{EHMINV_i}$ represents the minimum number of extra hours * doctor per day for week i.
$\mathrm{HV_i}$ represents the limit on the variation of hours * doctor per day between week i and $week\, i+1$.
$E\mathrm{HV_i}$ represents the limit on the variation of extra hours * doctor per day between week i and week i+1.
P represents the number of days planned for the service to operate.
D represents the average number of daily requests.
CT represents the standard time for the execution of the process (cycle time).
T represents the time factor that converts the number of planned days into weeks.
E represents the level of efficiency in the process.

The efficiency is an important parameter, it quantifies the percentage of time that is actually dedicated to the process and, consequently, the percentage of time that is wasted with voluntary or involuntary stops.

Decision variables

$\mathrm{x_i}$ number of hours * doctor per day in the week i.
$E\mathrm{x_i}$ number of extra hours * doctor per day in the week i.

Objective function

The purpose of the model is to minimize the total number of hours * doctor per day, per week, for the process, according to Equation 1. It is considered an additional penalty (C) for each extra hour used (overtime).

$$\text{Min } Z = \sum_i x_i + \sum_i Ex_i \times C \tag{1}$$

Constraints

Regarding the control of patients on the waiting list, the constraints presented in Expressions 2 and 3 were considered for a progressive reduction of the waiting list by limiting the maximum number of patients on the waiting list in the week $\mathbf{i}$. The left-hand side represents the number of consults to be performed in week $\mathbf{i}$ which must be equal or greater than the difference between the waiting list level in the previous week and the desired maximum waiting list level ($\mathrm{LMAX_i}$) in the current week:

$$\left(\frac{E \times 60 \times P \times T}{CT}\right)(x_i + Ex_i) \geq \left(LI + D \times P \times T\right) - LMAX_i \qquad \forall i = 1 \tag{2}$$

$$\left(\frac{\mathrm{E \times 60 \times P \times T}}{\mathrm{CT}}\right)(\mathrm{x_i} + Ex_i) \geq \left(\mathrm{LP_{i-1} + D \times P \times T}\right) - \mathrm{LMAX_i} \qquad \forall i > 1 \tag{3}$$

A minimum number of patients in the waiting list was also considered allowing better use of hospital resources without compromising the on-time responses to patients' requests. For achieving this behaviour Expressions 4 and 5 were modelled. The left-hand side represents the number of consults to be performed in week $\mathbf{i}$ which must be equal or less than the difference between the waiting list level in the previous week and the desired minimum waiting list level ($\mathrm{LMIN_i}$) in the current week:

$$\left(\frac{\mathrm{E \times 60 \times P \times T}}{\mathrm{CT}}\right)(\mathrm{x_i} + Ex_i) \leq \left(\mathrm{LI + D \times P \times T}\right) - \mathrm{LMIN_i} \qquad \forall i = 1 \tag{4}$$

$$\left(\frac{\mathrm{E \times 60 \times P \times T}}{\mathrm{CT}}\right)(\mathrm{x_i} + Ex_i) \leq (\mathrm{LP_{i-1} + D \times P \times T}) - \mathrm{LMIN_i} \qquad \forall i > 1 \tag{5}$$

This restriction (2-5) aims to define the limit values of the waiting list, considering the desired response times and to distribute the workload more evenly among the several weeks of analysis.

All MD perform several tasks other than consultation (e.g., surgeries, emergency room) so there are a limit number of hours that may be dedicated to consultation. Thus, a maximum limit was established for the number of hours * doctor per day. Expression 6 restrains the maximum number of hours * doctor per day in the week i ($\mathrm{HMAX_i}$):

$$\mathrm{x_i} \leq \mathrm{HMAX_i} \qquad \forall i \tag{6}$$

To avoid the existence of days with null capacity (no consultations performed) the constraint indicated by Expression 7 aims to ensure a minimum number of hours * doctor per day for week i ($\mathrm{HMIN_i}$):

$$\mathrm{x_i} \geq \mathrm{HMIN_i} \qquad \forall i \tag{7}$$

In view of the high number of patients waiting, and after a preliminary analysis of the real restrictions of the problem, it was concluded that it would be necessary to define the possibility of allocating overtime. It is a possibility that the administration is considering, if necessary, and so it would not be correct to increase the value of HMAX, as it is important to understand which times are not included for the availability of MD for the service under study. Thus, constraints to the maximum and minimum limits for the allocation of overtime were also established. Expression 8 shows the maximum number of Extra hours * doctor per day in the week i ($\mathrm{HMAX_i}$):

$$\mathrm{Ex_i} \le \mathrm{EHMAX_i} \qquad \forall i \tag{8}$$

The Expression 9 shows the minimum number of Extra hours * doctor per day for week i ($\mathrm{EHMIN_i}$):

$$\mathrm{Ex_i} \ge \mathrm{EHMIN_i} \qquad \forall i \tag{9}$$

In order to avoid major variations in the doctor's schedule between consecutive weeks, the Expressions 10 and 11 show restrictions for the definition of the limit variation on the number of hours * doctor per day between two consecutive weeks ($\mathbf{HV_i}$).

$$\mathrm{x_i} - \mathrm{x_{i+1}} \le \mathrm{HV_i} \qquad \forall i \tag{10}$$

$$\mathrm{x_{i+1}} - \mathrm{x_i} \le \mathrm{HV_i} \qquad \forall i \tag{11}$$

The maximum variation in the number of extra hours * doctor per day between two consecutive weeks ($\mathbf{EHV_i}$) is limited according to Expressions 12 and 13:

$$\mathrm{Ex_i} - \mathrm{Ex_{i+1}} \le \mathrm{EHV_i} \qquad \forall i \tag{12}$$

$$\mathrm{Ex_{i+1}} - \mathrm{Ex_i} \le \mathrm{EHV_i} \qquad \forall i \tag{13}$$

3.3.2. Context of application - Before the pandemic period

The application of the optimization model to the screening waiting list occurred with an essential principle – the involvement of MD in the improvement process through the development of a continuous improvement culture based on lean philosophy. For several months, weekly meetings were held with a team of orthopaedists to identify problems and find possible solutions implemented through improvement cycles inspired by Toyota Kata (Rother, 2010) and its PDCA cycles.

At the beginning of 2019, the number of requests in the waiting list for a first orthopaedic appointment was 4835 with an average waiting time of 210 days and for screening process were about 1244 patients with an average waiting time of 66 days. One of the main problems identified by MD and confirmed by the data analysis is related to the lack of response capacity, limited by the number of hours * doctor dedicated to the external consultations and more concretely to the first appointment, given the high number of referrals. Figure 3 shows this reality, showing the gap between capacity and demand. The number of scheduled consults corresponds to the capacity devoted to first consults, being shown in the figure in the form of vertical bars (representing the number of consults performed), and the demand requests are shown in the form of a line. It becomes clear the lack of capacity analysing the differences between consults performed and number of referrals (demand).

In 2018, the number of orthopaedic consults scheduled is much lower than the number of referrals received by the hospital in the same period. It is important to note that the numbers presented clearly show the number of requests (that represent patients) that accumulate every week increasing the waiting list, consequence of the scheduled consults not meeting the requests received. Another important characteristic of the data analysed is the variable behaviour of demand and also capacity (van Bussel et al., 2018).

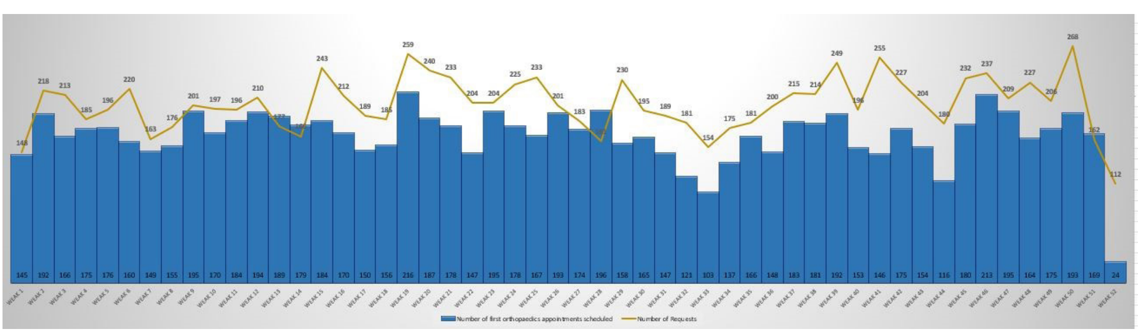

Figure 3. Comparison between the number of first orthopaedics appointments scheduled and the number of requests received, in 2018.

According to the orthopaedics doctors, many of the patients who are observed in the appointments were sent to the hospital without a previous study of the disease, namely without prescribed exams. It was also identified that several patients do not presented pathologies justifying an appointment in the hospital. Although such requests are not eligible for an appointment in the hospital, the orthopaedic doctors accept these referrals because they consider unacceptable to discard a request that is waiting for so long for the triage process. Thus, smaller times in the screening waiting list will possibly allow for more justifiable discards of requests contributing for the consistent reduction of the waiting list. The orthopaedic doctors admit that no triage time is defined in their schedules (the triage process was performed by good will in the emergency room in periods of low service demand). All these factors were contributing to the increase of the waiting list.

During this project, many constraints were identified, and different initiatives were promoted (Dinis-Carvalho et al., 2022), and the need to reduce the waiting list for screening process was one of the proposals that brought together more consensus within health professionals.

Following the same procedure, the model was applied to the consultation process, specifically to the first medical appointment. However, due to the pandemic, the face-to-face activities related to the continuous improvement project were interrupted. During this period, the optimization model was evolved for its application during and after pandemic contexts.

3.3.3. Context of application – During the pandemic period

In Portugal, due to the epidemic of the new coronavirus, SARS-CoV-2, the first lockdown was decreed in March 2020. Thus, among other restrictions, it was recommended by health authorities that the use of health services should be reduced to the essential. Despite the objective of mitigating the epidemiological infection by COVID-19, this is a measure envisaged as a way to increase the capacity of health services in the event of a pandemic or mass disaster (Dichter et al., 2014).

In this sense, following the recommendations of the health authorities, the lesser influx of non-urgent patients to the primary healthcare services was reflected in the reduction in the number of requests for first speciality appointments. In fact, the hospital's external consultation service adopted the closure of the service for three months. The reduction in the number of requests and the resumption of the programmed procedures promoted a reduction of the waiting list for first appointments. Thus, at the end of March 2021 the waiting list for first orthopaedics appointments had 1106 patients with an average waiting time of 98 days.

The application of the optimization model to the waiting list for first appointment considering different scenarios intends to demonstrate the versatility of the model and in the same way to present a solution for the different behaviour possibilities of the system.

4. Results

4.1. Screening waiting list

The optimization model was applied to the waiting list for screening and presented the optimal solution fulfilling all restrictions. The parameters were defined according to the information collected from the historic data and to the knowledge of MD about the process. For LI of 1244 patients, the maximum limits of the list were established in up to 400 patients, with respect to LMAX, considering a gradual reduction of 40 patients and 300 patients for LMIN. It was considered the demand D verified in 2018 (42 patients per day) for a period P of 244 effective working days. The efficiency value was validated by health professionals at 80% for the 6-minute cycle time (CT) process. Regarding HMAX and HMIN, 8 and 4 hours were considered, respectively, according to the possibility of making these medical hours available for the screening process.

The optimal solution presented by the model for the minimum number of hours needed to reduce the waiting list was 1400 hours * doctor for a time horizon of 52 weeks (Vieira et al., 2020).

Several approaches were parameterized and tested with the model (e.g. regarding the level of intensity of the waiting list reduction and the time horizon for such reduction). These results were explored with the team and given the consensus that an effective screening can improve on the performance of the service, a doctor was allocated, temporarily, exclusively dedicated to the screening process. Thus, it was possible to reduce the screening process average waiting time to 7 days in just 12 weeks.

4.2. Waiting list for first medical appointment

4.2.1. Scenario 1: Before pandemic

Considering the information collected previously, in the analysis of the data and with health professionals, the optimization model was applied to the waiting list for first medical appointment with the same parameters defined for the screening waiting list. However, considering the characteristics of the waiting list and the medical appointment process, LI of 4835 patients and CT of 16.35 were defined. Although when scheduling appointments a 15-minute consultation time and cycle is defined, as observed in 2018, the CT performed is higher. Likewise, according to historical production data, HMAX is 11 hours and HMIN is 2 hours.

Since the amount of overtime that can be attributed has not been confirmed, departing from common assumption in previous studies is that health capacity could be acquired on a constant basis cost fee (Chen et al., 2020), 8 hours for EHMAX and 0 for EHMIN were establish representing the equivalent of a full-time doctor dedicated to the first appointment process.

The scenario depicted in Figure 4 represents a consistent moderate reduction of the waiting list during the planning time horizon.

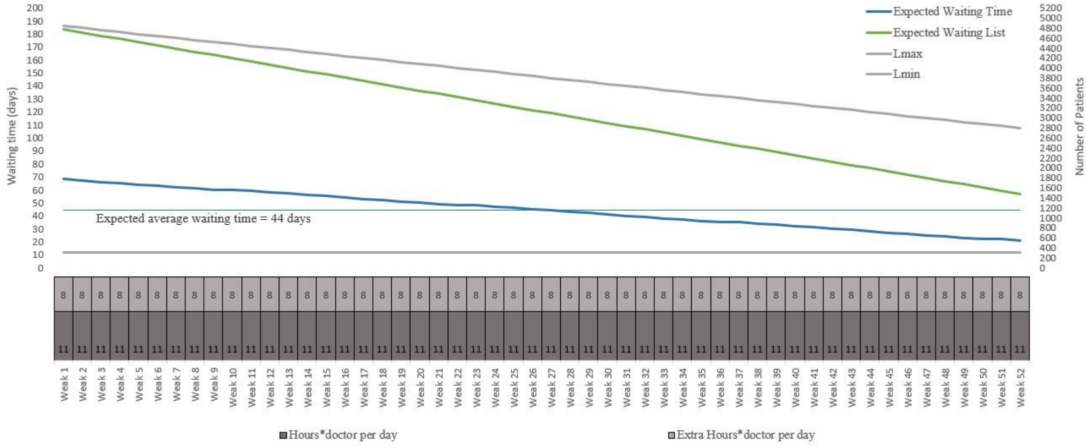

Figure 4. Optimal solution for the reduction of first appointment waiting list.

Although it may represent a soft imposition to the LMAX constraint, the fact is that the maximum capacity is required throughout the time horizon (normal day hours and overtime hours) which converts into a linear behaviour of the forecasted waiting list. During the planning period the average waiting time would be 44 days and by the end of the time horizon the waiting time would be near 20 days. This scenario would represent the optimal approach to solve the waiting list problem by meeting the constraints related to the maximum and minimum capacity allowed. This scenario would also allow a steady reduction of the waiting list facilitating resources utilization planning. Due to the pandemic hospital operational procedures changed and other scenarios were tested to depict several approaches for solving the waiting list problem during and after the pandemic.

4.2.2. Scenario 2: Current waiting list and demand

This scenario represents the same constraints and variables however to a LI of 1106 patients and D equal to 20 patients per day.

The optimal solution presented by the model that meets all restrictions is 2520 hours, as shown in Figure 5.

The proposed scenario imposes a steady waiting list reduction during 19 weeks and then stabilizes the LMAX in 400 patients which was found to be an accepted value regarding the consequent waiting time. As can be seen, there is no need for overtime hours and a pattern appears when the model enters the stabilized period which can also represent stabilized planning of resource needs. The average waiting time would be 16 days which would tend to stabilize in lower values as the model continues through the stabilized period. This scenario assumes that hospital operational procedures allow such patients in-flow.

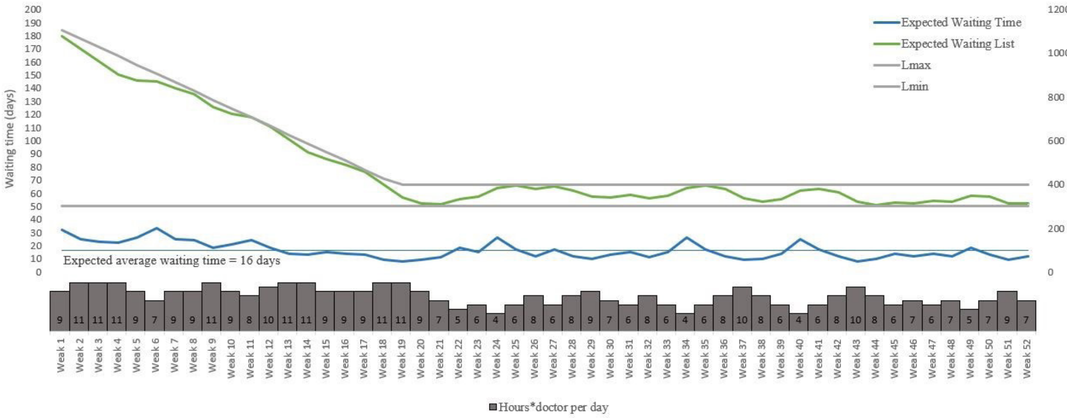

Figure 5. Optimal solution to the first appointment in the current context.

4.2.3. Scenario 3: Better user experience

According to clinical criteria, although the fact that each doctor may decide what time is dedicated to each patient, there is a recommended consultation time. For the first orthopaedic appointment this time was set at 20 minutes. In this sense, this scenario was tested considering a CT equal to 20 minutes to promote a better user experience (by avoiding rush appointments). This scenario implements the same assumptions as the previous scenario with the only intent to understand the additional stress in resources utilization, meaning, the amount of hours * doctor needed to comply with the constraints. By increasing 22% the appointment CT the total number of hours * doctor needed increases 460 hours (including 13 overtime hours), according to the optimal solution presented in Figure 6.

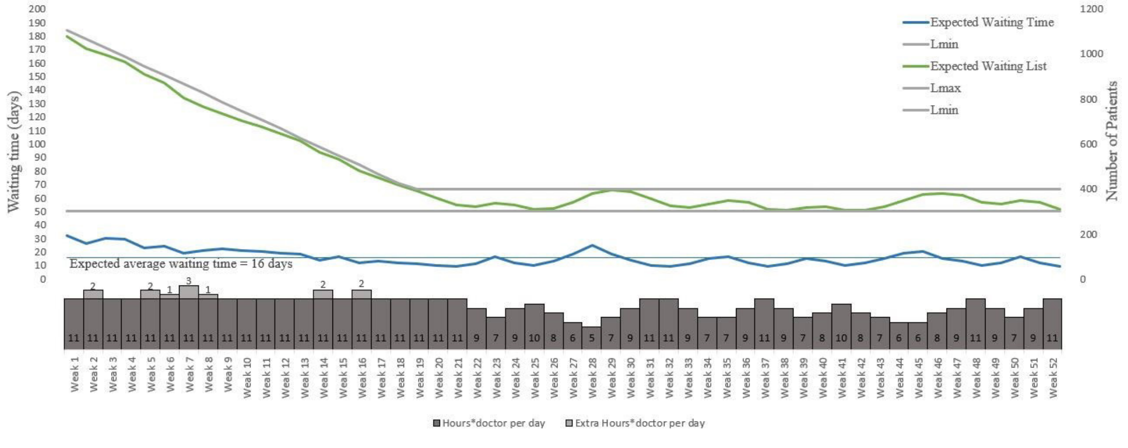

Figure 6. Optimal solution to the first appointment considering the promotion of a better user experience.

Due to the high flexibility of the model, it is possible to parameterize and test successive scenarios. So, to avoid the use of overtime hours that are much more expensive to the hospital, a more soft and gradual waiting list reduction was imposed during the first 36 weeks (Figure 7). The behaviour of the forecasted waiting list is identical to the previous test but without using any overtime hours, however promoting an increase in the average waiting time to 19 days.

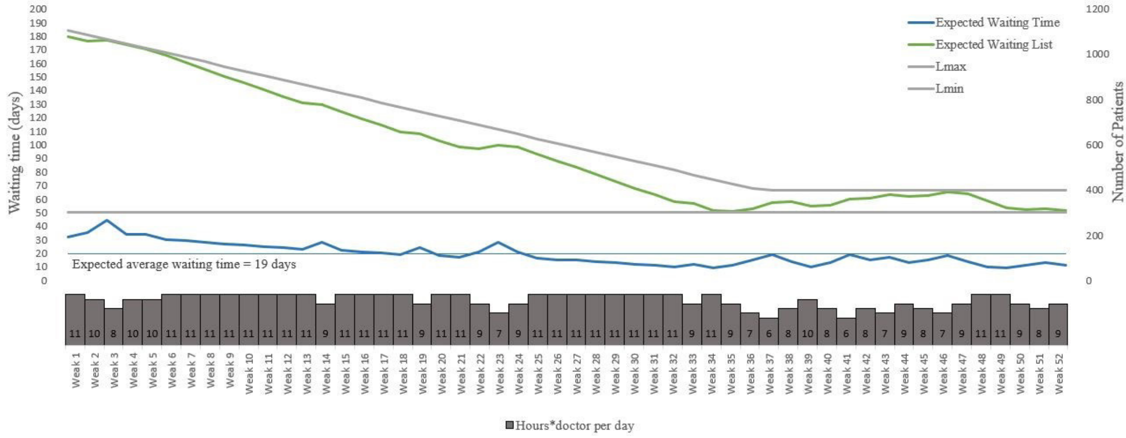

Figure 7. Optimal solution to the first appointment considering a more soft and gradual waiting list reduction.

4.2.4. Scenario 4: Seasonal planning

The hospital funds are assigned by the regulatory health institutions that occasionally charge the hospital with additional funds to promote hospital service improvement. The seasonal planning scenario intents to replicate the real scenarios in which additional funding is assigned to hospital so it can impose waiting list reduction. In this scenario a demonstration is made regarding two seasonal extra funding, as shown in the Figure 8 that also presents the solution presented by the model.

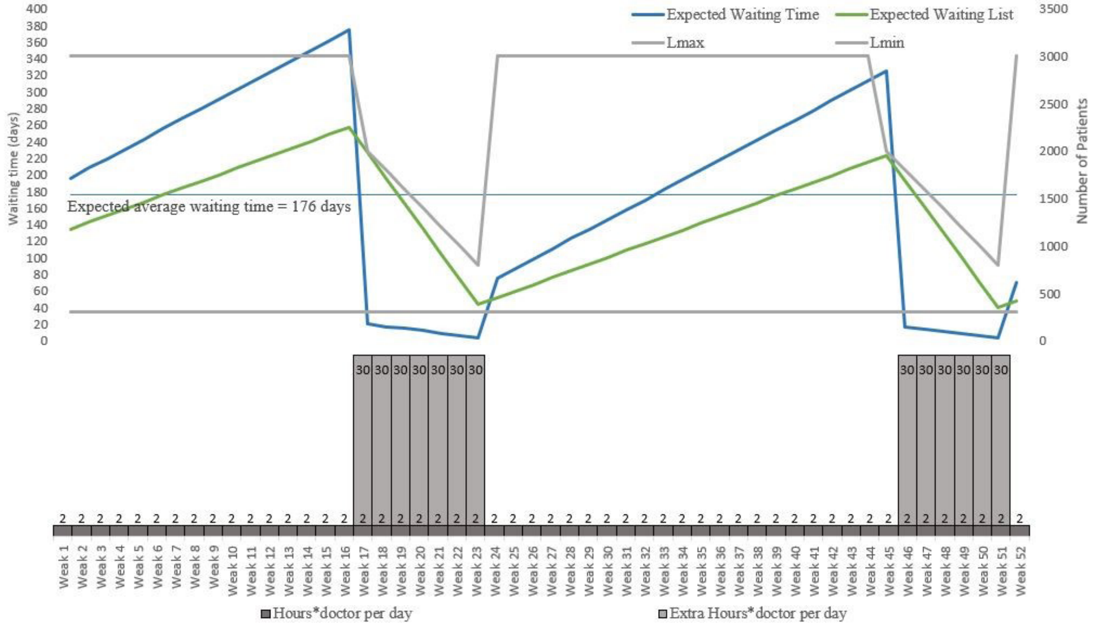

Figure 8. Optimal solution for a seasonal planning.

By parameterizing a relaxation on the LMAX constraint the waiting list is allowed to increase as the minimum number of hours * doctor is used. Then, in two different periods in the time horizon a heavy reduction on the waiting list is imposed coincidental to the extra budget availability.

This allows the hospital to hire overtime hours and perform the waiting list decrease. This type of operational approach is very common in public health hospitals. This scenario presents and average waiting time of 176 days.

5. Discussion

In each scenario the number of hours * doctor (ordinary and extra) represents the minimum number of hours to allow the fulfilment of all constraints. The number of hours * doctor represents the production intensity needed to comply with the model parameterization demand. The expected behaviour of the waiting list (number and time) directly relies on the number of hours * doctor that the model computes. The waiting list waiting times are a function that depends on the number of consultations performed given a predefined cycle-time and a number of hours * doctor. As more consultations are performed the waiting list waiting times are reduced. So, increasing or decreasing the number of hours * doctor will have a decisive impact on the waiting list (number of patients waiting) and consequently on the waiting times (time that patients wait in the waiting list).

The optimization model proves to be an adequate tool for dealing with the waiting list reduction problem by generating optimal solutions for the desired scenarios.

In scenario 1 and 2 a smooth waiting list reduction was imposed to gradually achieve better response times. Scenario 3 tests the possibility of increasing the consults time so that it can be translated into higher patient satisfaction and general better experience. The results show that it can be achieved at the expense of more hours needed although no extra hours are needed. Scenario 4 explores the common approach of seasonal extra funding allowing for seasonal heavy waiting list reduction by applying extra hours.

Considering the budget restrictions and usual limitations of extra specialized resources, the tested scenarios did not consider the complete eliminate of the waiting list, and instead defined acceptable levels of waiting list (and consequent waiting time). The objective is to define the minimum number of resources' capacity that allow an acceptable system behavior that complies with all health regulators guidelines.

The model flexibility allows to test several other scenarios that the hospital management considers appropriate. In fact, the model has a buil-in feature that allows the managers to manually control the model parameters and decision variables so that they have maximum control over the model behavior. This is especially important when trying to replicate a custom real scenario. The built-in feature throws alerts when a model constraint is violated and identifies the values that are causing the problem. By doing so, the model guides the manager to obtain a feasible solution for the custom problem.

The optimization model can simulate several real-case scenarios which endow the hospital management with a powerful analysis tool for decision making. The model was tested and validated in the orthopaedics speciality however it can be used by any other medical speciality. In fact, the proposed approach may be systematized and spread to all medical specialities (Figure 9).

The first step is the data gathering and information processing. This means that is mandatory to collect all the important data regarding the system parameterization and then process it into useful information. Next the optimization model must be feed with the processed information that characterizes the system. When all information is introduced in the model several scenarios should be simulated according to the organizational guidelines. After scenarios generation the managers should analyze the results and decide on about the actions to apply. After applying the actions, the system status monitoring phase takes place in which the progress of the actions is monitored. Periodic management meeting should analyse the system status and decide whether actions are resulting as planned or if extra actions are needed. If no more actions are needed, then the system status monitoring phase should again be the focus. However, if more actions are needed, then the new information must be processed and feed to the optimization model, reinitiating the systematization approach for waiting list problem solving.

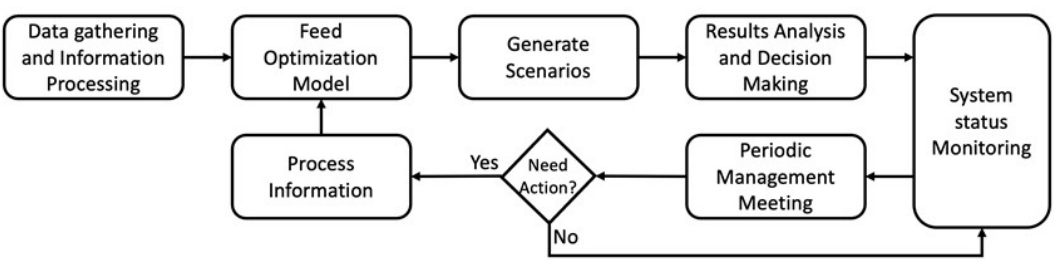

Figure 9. Problem-solving systematization approach diagram.

6. Concluding remarks

Continuously better health systems is what countries try to deliver to its citizens. However, heavy budget constraints limit the availability of resources needed to provide the health systems. Hospitals have to operate under contexts of budget limitations and high demand patterns. Moreover, more than higher demand, hospitals have to deal with higher patients' expectations regarding service quality.

The proposed model is capable of defining the needed capacity in terms of hours * doctor to meet imposed requirements in terms of waiting list levels. It can also differentiate between normal working hours and overtime hours. The model can represent real scenarios and deliver OSs. It also allows the manual control of the model throwing alerts if constraints are not met so guiding the user to achieve a feasible solution.

The model was developed in excel and uses a freeware solver which means that public institutions do not need to invest extra budget as long as they have access to excel software. This enhances the systematization approach proposed. The model may be applied to any hospital specialty and become powerful decision-making support tool.

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