Dynamic Management of Appointments in Sanitary Environments: a Systematic Literature Review

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Abstract

The aim of this study is to provide an extensive systematic literature review about the use of dynamic programming in the management of appointments in health centers, providing a view of the current research environment. Dynamic programming of appointments improves the efficiency through algorithmic decision support tools. This technology has used successfully in other industries such as airlines, car rental agencies and hotels. The application of this technique to the health environment has attracted the interest of many academics in the last 50 years because it is very useful to improve the access and the quality of health systems and also reduce the cost. However, the use of these techniques in health settings is not trivial because every decision is vital for patients. In addition, we must consider other important and complex factors such as emergencies. Therefore, we hope to analyze the current state of this technology in the health environment, identifying keys for future research.

1 Introduction

The objective of this work is to provide an extensive review of the literature about the use of dynamic programming in the management of appointments in health centers. This theme has attracted the interest of many academics over the past 50 years, from the pioneering works of Bailey (1952) and Lindley (1952).

Health care providers are under great pressure to reduce costs and improve the quality of service. In recent years, given the greater emphasis on preventive medicine, the ambulatory or the primary level of health are gradually becoming an essential component in health care.

When we add factors to health care budgets such as aging of the population and the increase of the chronic diseases, it is not surprising that there is a growing pressure on health service to improve the efficiency.

Appointment systems can be a source of dissatisfaction for patients and healthcare professionals. Patients often complain about the lack of availability. To mitigate this discontent, we might think of reducing the time of patient care sessions. However, in Spain only six minutes per patient is allocated in average. In fact, health professionals are disappointed with it since they have to make quick decisions about the health of their patients. Thus, the scheduling systems of appointments are in the intersection between efficiency and the correct access to health services.

In this paper we offer a comprehensive research study on the programming of dynamic appointments in health environments. These models have the potential to improve efficiency through algorithmic decision support tools. This technology has used successfully in other industries such as airlines, car rental agencies and hotels (Talluri and Van Ryzin, 2004). We believe that decision support techniques can reduce costs and improve access to health services simultaneously.

Designing a dynamic appointment scheduling system aims to adapt to the demand, with the availability of the resources, and, at the same time, optimize the use of those resources and minimizes the waiting times that patients suffer. In addition, it is imperative to take into account and understand the health environment in which we are, outpatient, hospital, specialized centers, etc. It is necessary to pay special attention to the factors that make appointment scheduling challenging. In conclusion, to offer a roadmap in appointment management design in health centers.

Waiting time and congestion in waiting rooms are two of the few tangible elements of quality. Surveys indicate that excessive waiting time is often the main reason why patients are dissatisfied with the health services offered (Huang, 1994).

Many factors affect the performance of appointments systems. The delay of patients and specialists, as well as possible emergencies are the main factors.

Emergencies are a key factor in the design of a system that allows us to manage efficiently the demand and the resources. A good appointment system should provide convenient access to health services for all patients. However, how do we prioritize emergencies? Patients' needs have different degrees of urgency, and the decision-

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making process we are proposing must be automatic. That is, decisions must be made before having complete information about urgency.

In conclusion, we wish to deepen in this theme and present the general considerations to be taken into account in the modeling of problems. Therefore, we provide a taxonomy of the methodologies used in the existing literature and we can help to understand how to model a dynamic appointment system.

2 Review Process

This study has been undertaken as a systematic literature review (SLR) based on the original guidelines as proposed by Kitchenham (B.A. Kitchenham *et al.*, 2004) to achieve the goal described in Section 1: provide an extensive review of the literature about the use of dynamic programming in the management of appointments in health centers. A systematic literature review allow identifying, evaluating and interpreting all available research data relevant to a particular research question in a specific investigation area. The guides proposed, which are among the most widely accepted in software engineering, have been followed to carry out this work.

These guidelines establish that a review should comprise three phases: planning, conducting and reporting. The planning activity deals with developing the review protocol as well as deciding how the researchers should work and interact to conduct the review. This protocol prescribes a controlled procedure for executing the review and includes research questions, search and evaluation strategies, inclusion/exclusion criteria, quality assessment, data collection form and methods of analysis. The second phase focuses on executing the protocol as it has been defined. Finally, the last phase describes how the final report has been elaborated.

2.1 Research Questions

To begin the present study, we search similar systematic reviews following the planned searches that its described in the present and the following subsection. The results obtained are described below.

Two literature reviews were found. Both are from more than five years ago, but they are very useful to start in the world of dynamic appointment management, as well as recognizing the main properties to take into account. Due to its high interest and although one of them is of the year 2003 and fails one of the quality requirements mentioned in section 2.3, it has been considered.

On the one hand, in the oldest review of the selected ones, made by (Cayirli and Veral, 2009), we can find an analysis of the main characteristics to take into account when you want to design a system to manage appointments in a health environment as faithful as possible. Among other properties, we focus on those properties that make appointment's programming a challenge. Among them, it is necessary to highlight the number of patients that can be placed in a time zone, the prioritization of patients, and the function to be optimized. In addition, we find other characteristics to consider in the process of patients' arrivals, like the possible unpunctuality or absence of patients and/or professionals, as well as urgencies.

On the other hand, (D Gupta and Denton, 2008) present a constructive criticism of the studies which are done until the date. As a consequence, this article proposes other aspects, besides those mentioned in (Cayirli and Veral, 2009). Such aspects have to be taken into account as main attributes when we want to develop a dynamic appointment management system: service time (e.g., difficult to assign a fixed time to a Surgery), doctor's and patient's preferences (e.g., a patient usually wants to see your doctor, schedules) and indirect waiting time (e.g., time from appointment until appointment day). Also, this work studies the complexity of these properties in a sanitary environment (outpatient, outpatient appointment and surgery). This aspect is very interesting and adverts us how we must design a tool to support decision making in appointment management exclusively for physicians and the environment, without considering patients.

From these reviews, we pretend to make a study to see the advances made in the technique to the present date. For that, we focus on all the studies that consider the patient as the main user to take into account. Also, it is important not only to take into account the patient waiting time on the day of their appointment, but also to contemplate the time that passes from an appointment until the date of the appointment, because, surely, it is related to the probabilities of cancellation and delay.

Based on these, some questions are asked to be completed in this new systematic review of the literature.

RQ1. Are there currently applications that use dynamic programming to help manage patients in the healthcare environment?

RQ2. Are the patient's preferences taken into account when making an appointment?

RQ3. What health environments have adopted dynamic programming for managing appointments? Differences to keep in mind?

RQ4. How to mitigate the effects of cancellations and non-presentations of patients?

RQ5. Is the time between the request of the appointment and the day of the appointment (indirect time) taken into account?

RQ6. How to manage emergencies and their priorities?

2.2 Search Strategy

This section details how the search for related articles has been done. The keywords used and the chosen bibliographic engines are presented.

At first, some keywords were defined which were increasing as related articles were found since we learned from the keywords of those articles found.

After several tests, the keywords are concluded in Table 1.

A1. Health	B1.Dynamic	C1.Appointment	D1. Programming D2. Scheduling	E1. Review E2. Software

Table 1 *Keywords*

In addition, Table 2 presents the search expressions representing the different combinations of keywords done for the search.

"A1 AND B1 AND D2"	Health dynamic scheduling
"A1 AND B1 AND D2 AND E1"	Health dynamic scheduling review
"A1 AND B1 AND C1 AND D2"	Health dynamic appointment scheduling
"A1 AND B1 AND C1"	Health dynamic appointment
"B1 AND C1 AND E2 AND A1"	Dynamic scheduling software health

Table 2 *Search terms*

In order to perform the search, we considered the Google Scholar, Fama (catalog of magazines and books of the University of Seville), IEEE, Scopus and PubMed data sources. In them, the search expressions (cf. Table 2) were introduced for obtaining new revisions and studies that conclude some of the challenges raised in section 2.1.

The articles collected from the different databases were managed through the Mendeley tool.

2.3 Inclusion and exclusion criteria

Thereafter, we define the admission and exclusion criteria. With those criteria, we justify whether to consider or not the articles which are found on the aforementioned search engines. Thus, we can identify the most relevant articles to develop our review of the literature.

The inclusion/exclusion criteria are carried out in five phases presented in Table 3.

Phase	Inclusion/exclusion criteria
P1	Article related to dynamic scheduling of appointments in the health field. Inclusion of keywords.
P2	Publications since 2006
P3	Availability of the full text for free.
P4	Not duplicated
P5	Number of citations relevant, always keeping in mind its year of publication. If an article has been released in a date close to the present, it is logical to find few citations. However, if an article has been in circulation for several years and its number of citations has not increased in relation, we can consider it as a signal of the quality of that article.

Table 3. *Inclusion and exclusion criteria*

However, it should be mentioned that in the second phase (i.e., publications since 2006), some articles have not been taken into account for the article. Although it does not achieve the requirement, it is very useful to immerse ourselves in the world of dynamic programming in healthcare environments, giving an overview of everything that has to be taken into account. Therefore, it was decided not to exclude them.

2.4 Quality criteria

In this section, we determine the quality criteria. Once the articles have exceeded the criteria of admission and exclusion, the article' properties are evaluated to know their quality. Each quality judgment can take the values yes or no and, in some cases, including the value "partially". All the quality criteria considered and their possible values are explained in Table 4.

QA	Values
QA1. Is the text readable?	O Yes: it is possible to read and understand without being an expert on the subject. O Partially: In certain aspects, it is necessary prior experience. O No: difficult to understand.
QA2. Limitations have been described?	O Yes: define the limits of the study done. O No: does not describe the boundary of the study developed.
QA3. There are future lines of research?	O Yes: present a series of ideas to continue the research. O No: there are not claims on possible innovations.
QA4. Have the results been presented?	O Yes: presents the results obtained in the study. O Partially: reference to other articles. O No: does not clarify the results of the investigation.
QA5. Has the algorithm been tested?	O Yes: health domain analysis. O No: the characteristics of the health area are not detailed.
QA6. Has the health application environment been described?	O Yes: health domain analysis. O No: the characteristics of the health area are not detailed.
QA7. Has the cost function to optimize been defined?	O Yes: description of the function to be maximized or minimized. O No: the optimization function is not detailed.

Tabla 4. *Quality criteria*

2.5 Characterization Scheme

In order to evaluate and classify the selected articles, a scheme dedicated to organizing and cataloging the

information found in the articles is made. Thus, it is easy to have an overview of each article. Based on this scheme, we describe the results obtained responding to the research questions described in section 2.1.

In Table 5 we illustrate the schema definition, and in section 3.2 we instantiate it with the selected articles.

Characterization Scheme

Element	Characteristic	Value
General Information	Author	{}
	Year	{}
	Title	{}
	Number of citations	{}
	Journal	{}
	Source	{}
	Theoretical/experimental	{Theoretical with reviews to experimental studies, theoretical studies, experimental studies}
Modelling	Area of application	{External consultations, treatment, surgery, outpatients clinics, nursing, combination of the above}
	Delays	{Theoretical, Experimental, No}
	Cancellations	{Theoretical, Experimental, No}
	Patient's preferences	{Theoretical, Experimental, No}
	Emergencies	{Theoretical, Experimental, No}
	Prioritization of emergencies	{Theoretical, Experimental, No}
	Attention to the time passed between the request of the appointment and the day of the appointment	{Theoretical, Experimental, No}
	Cost function to optimize	{Patient waiting time, physician downtime, cost reduction, time from appointment request to appointment day, combination of the above}
Results	Results presented	{Yes (mentioning other studies), Yes, No}
	Test results	{simulation, case study, both, Statistical, No (is a literature review)}

Table 5. *Characterization Scheme*

With the General Information element we pretend to collect the main characteristics of the selected articles,

including the Author, Year, Title of the article, the Journal and the Source where it was written.

In the Modelling, it is tried to visualize in which articles we can find answers to the research questions RQ2, RQ3, RQ4, RQ5 and RQ6, as well as for QA6 and QA7 quality criteria.

Finally, we expose the form of resolution and the response of the QA4 and QA5 quality criteria in the Result element.

3 Results

This section presents the results obtained after doing the planning described in section 2. First, we explain the results obtained in the various searches performed. After that, we evaluate these articles according to the quality criteria defined in section 2.4.

3.1 Search results

The search process was developed with the keywords described in section 2.2 and introducing them into the bibliographic engines specified in section 2.2. Once the results were obtained, it was checked which the inclusion and exclusion criteria. After this, the number of articles was considerably reduced, finding difficulties to select a number of notable articles to perform a good systematic review.

The first search was made in Google Scholar, not finding any new articles in the other databases, besides those already provided by Google Scholar. In addition, FAMA is discarded since it was not possible to collect any article related to the subject.

In Figure 1 and Figure 2 we can graphically display the number of articles included and excluded by inclusion and exclusion criteria respectively.

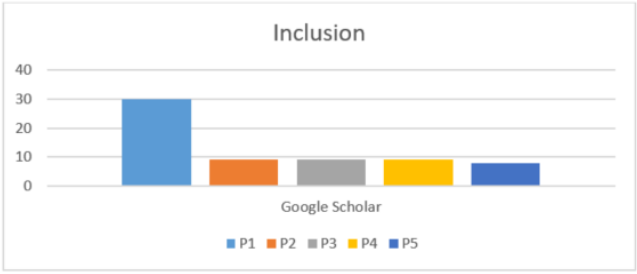

Figure 1. *Inclusion criteria*

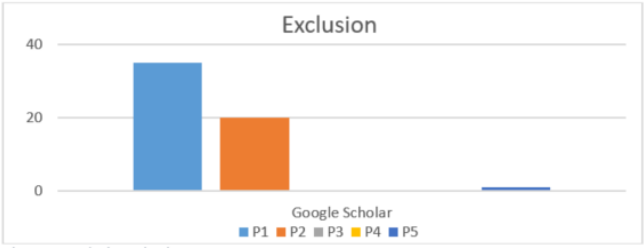

Figura 2. *Exclusion criteria*

The inclusion/exclusion phase that restricts most the search is the first. With the first criteria, we are sure that we select articles related to the management of dynamic appointments in health environment, and the keywords are chosen are in the article.

Subsequently, phase 2 (i.e., articles published in the last ten years) also excludes a considerable number of studies. This criterion helps us to make a review of the most current literature.

3.2 Analysis of selected articles

Finally, we highlight eight articles by instantiating the schema definition designed in section 2.5 (Table 6 – Table 13).

Schema of Appointment scheduling in health care: Challenges and opportunities article

Element	Characteristic	Value
General Information	Author	Diwakar Gupta and Brian Denton
	Year	2008
	Title	Appointment scheduling in health care: Challenges and opportunities
	Number of citations	385
	Journal	IIE Transactions
	Source	Graduate Program in Industrial & Systems Engineering, Department of Mechanical Engineering, University of Minnesota
	Theoretical / Experimental	Theoretical with reviews of experimental studies
Modelling	Area of application	Combination (External consultation, Outpatient clinic and Surgery)
	Delays	Theoretical
	Cancellations	Theoretical
	Patients' preferences	Theoretical
	Emergencies	Theoretical
	Priority of emergencies	Theoretical
	Attention to the time passed between the request of the appointment and the day of the appointment	Theoretical
	Cost function to optimize	Combination of waiting time suffered by the patients and time of inactivity of the doctor)
Results	Results presented	Yes (mentioning other studies)
	Test results	No (it is a literature review)

Table 6. *Schema of Appointment scheduling in health care: Challenges and opportunities article*

Schema of Outpatient Scheduling in Health Care: a Review of Literature article

Element	Characteristic	Value
General Information	Author	Tugba Cayirli and Emre Veral
	Year	2003
	Title	Outpatient Scheduling in Health Care: a Review of Literature
	Number of citations	535
	Journal	Production and Operations Management Society
	Source	Hofstra University, Department of Management, New York
	Theoretical / Experimental	Theoretical with reviews of experimental studies
Modelling	Area of application	External consultation
	Delays	Experimental
	Cancellations	No
	Patient's preferences	No
	Emergencies	Experimental
	Priority of emergencies	No
	Attention to the time passed between the request of the appointment and the day of the appointment	No
	Cost function to optimize	Combination of waiting time suffered by the patients and time of inactivity of the doctor)
Results	Results presented	Yes (mentioning other studies)
	Test results	No (it is a literature review)

Table 7. *Schema of Outpatient Scheduling in Health Care: a Review of Literature article*

Schema of Dynamic Scheduling of Outpatient Appointments Under Patient No-Shows and Cancellations article

Element	Characteristic	Value
General Information	Author	Nan Liu, Serhan Ziya and Vidyadhar G. Kulkarni
	Year	2010
	Title	Dynamic Scheduling of Outpatient Appointments Under Patient No-Shows and Cancellations.
	Number of citations	139
	Journal	-
	Source	Department of Statistics and Operations Research, University of North Carolina
	Theoretical / Experimental	Experimental
Modelling	Area of application	External consultations
	Delays	Experimental
	Cancellations	Experimental
	Patient's preferences	Experimental
	Emergencies	No
	Priority of emergencies	No
	Attention to the time passed between the request of the appointment and the day of the appointment	Experimental
	Cost function to optimize	Cost reduction
Results	Results presented	Yes
	Test results	simulation

Table 8. *Schema of Dynamic Scheduling of Outpatient Appointments Under Patient No-Shows and Cancellations article*

Schema of Designing appointment scheduling systems for ambulatory care services article

Element	Characteristic	Value
General Information	Author	Tugba Cayirli, Emre Veral and Harry Rosen
	Year	2006
	Title	Designing appointment scheduling systems for ambulatory care services.
	Number of citations	209
	Journal	-
	Source	Hofstra University, Department of Management
	Theoretical / Experimental	Experimental
Modelling	Area of application	Outpatients clinics
	Delays	Experimental
	Cancellations	No
	Patient's preferences	No
	Emergencies	Experimental
	Priority of emergencies	No
	Attention to the time passed between the request of the appointment and the day of the appointment	No
	Cost function to optimize	Combination of waiting time suffered by the patients and time of inactivity of the doctor)
Results	Results presented	Yes
	Test results	simulation

Table 9. *Schema of Designing appointment scheduling systems for ambulatory care services article*

Schema of Dynamic multi-appointment patient scheduling for radiation therapy article

Element	Characteristic	Value
General Information	Author	Walter J. Gutjahr, Marion S. Raunerb
	Year	2012
	Title	An ACO algorithm for a dynamic regional nurse-scheduling problem in Austria
	Number of citations	41
	Journal	Elsevier
	Source	Sauder School of Business, University of British Columbia
	Theoretical / Experimental	Experimental
Modelling	Area of application	Treatment
	Delays	Experimental
	Cancellations	No
	Patient's preferences	Theoretical
	Emergencies	Experimental
	Priority of emergencies	No
	Attention to the time passed between the request of the appointment and the day of the appointment	No
	Cost function to optimize	Waiting time patients
Results	Results presented	Yes
	Test results	simulation

Table 10. *Schema of Dynamic multi-appointment patient scheduling for radiation therapy article*

Schema of Dynamic scheduling with due dates and time windows: an application to chemotherapy patient appointment booking article

Element	Characteristic	Value
General Information	Author	Yasin Gocgun and Martin L. Puterman
	Year	2014
	Title	Dynamic scheduling with due dates and time windows: an application to chemotherapy patient appointment booking
	Number of citations	10
	Journal	Health Care Management Science
	Source	Centre for Maintenance Optimization Reliability Engineering, Department of Mechanical Industrial Engineering, University of Toronto and Operations and Logistics Division, Sauder School of Business, University of British Columbia,
	Theoretical / Experimental	Experimental
Modelling	Area of application	Treatment
	Delays	Experimental
	Cancellations	Experimental
	Patient's preferences	No
	Emergencies	Experimental
	Priority of emergencies	Experimental
	Attention to the time passed between the request of the appointment and the day of the appointment	No
	Cost function to optimize	Cost reduction
Results	Results presented	Yes
	Test results	simulation

Table 11. *Schema of Dynamic scheduling with due dates and time windows: an application to chemotherapy patient appointment booking article*

Schema of Clinic Overbooking to Improve Patient Access and Increase Provider Productivity article

Element	Characteristic	Value
General Information	Author	Linda R. LaGanga and Stephen R. Lawrence
	Year	2007
	Title	Clinic Overbooking to Improve Patient Access and Increase Provider Productivity
	Number of citations	180
	Journal	Decision Sciences Institute
	Source	Mental Health Center of Denver and University of Colorado at Boulder
	Theoretical / Experimental	Experimental
Modelling	Area of application	Outpatients clinics
	Delays	Experimental
	Cancellations	Experimental
	Patient's preferences	No
	Emergencies	Experimental
	Priority of emergencies	No
	Attention to the time passed between the request of the appointment and the day of the appointment	No
	Cost function to optimize	Cost reduction
Results	Results presented	Yes
	Test results	simulation

Table 12. *Schema of Clinic Overbooking to Improve Patient Access and Increase Provider Productivity article*

Schema of Revenue management for a primary care clinic in the presence of patient choice article

Element	Characteristic	Values
General Information	Author	Diwakar Gupta and Lei Wang
	Year	2008
	Title	Revenue management for a primary care clinic in the presence of patient choice.
	Number of citations	119
	Journal	Operations Research
	Source	Department of Mechanical Engineering, University of Minnesota, Minneapolis, Minnesota and SmartOps Corporation, Pittsburgh, Pennsylvania
	Theoretical / Experimental	Experimental
Modelling	Area of application	Outpatients clinics
	Delays	No
	Cancellations	No
	Patient's preferences	No
	Emergencies	Experimental
	Priority of emergencies	Experimental
	Attention to the time passed between the request of the appointment and the day of the appointment	No
	Cost function to optimize	Cost reductions
Results	Results presented	Yes
	Test results	Statistical

Table 13*. Schema of Revenue management for a primary care clinic in the presence of patient choice article*

We study the distribution of these articles over time thanks to Figure 3.

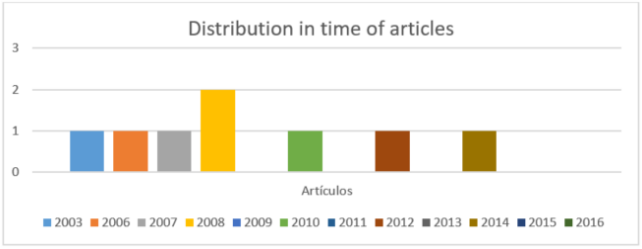

Figure 3. *Distribution in time of articles*

Although we initially wanted to obtain articles from the last 10 years, we can conclude that this claim was too ambitious. We have got only eight articles and few are close to the current year. On the contrary, it is easier to find articles related to the subject before 2010. However, we wanted to maintain the initial idea, in order to try to write a literature review as current as possible.

With relation to the source of each article, note that all articles have been found in all of the chosen bibliographic sources. That is, no article was discovered exclusively in any of the sources.

3.3 Quality of selected articles

Having commented the selected articles, we proceed to evaluate the quality of these according to the norms defined in section 2.4. This evaluation is shown in Table 14.

	QA1	QA2	QA3	QA4	QA5	QA6	QA7
Appointment scheduling in health care Challenges and opportunities	Yes	Yes	Yes	Partially	Partially	Yes	Yes
Outpatient Scheduling in Health Care: a Review of Literature	Yes	Yes	Yes	Partially	Partially	Yes	Yes
Dynamic Scheduling of Outpatient Appointments Under Patient No-Shows and Cancellations	Partially	Yes	Yes	Yes	Yes	Yes	Yes
Designing appointment scheduling systems for ambulatory care services	Partially	Yes	Yes	Yes	Yes	Yes	Yes
Dynamic multi-appointment patient scheduling for radiation therapy	Partially	Yes	No	Yes	Yes	Yes	Yes
Dynamic scheduling with due dates and time windows: an application to chemotherapy patient appointment booking	Partially	Yes	No	Yes	Yes	Yes	Yes
Clinic Overbooking to Improve Patient Access and Increase Provider Productivity	Partially	Yes	Yes	Yes	Yes	Yes	Yes
Revenue management for a primary care clinic in the presence of patient choice.	Partially	Yes	No	Yes	Yes	No	Yes

Table 14. *Quality os articles*

In Figure 4 we visualize the percentage of quality, differentiating the possible values that can take, indicated in section 2.4.

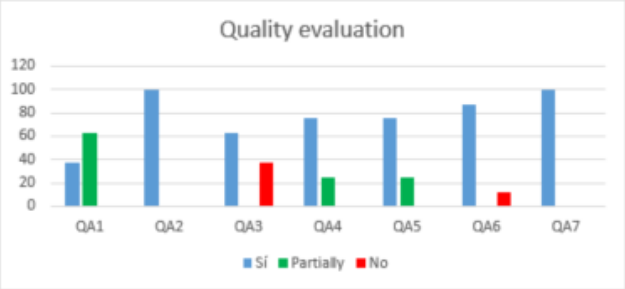

Figure 4. *Quality evaluation*

The QA2 and QA7 quality criteria are perfectly satisfied with 100% of acceptance. On the one hand, we found, thanks to QA1, that reading about 60% of the articles is a bit difficult if one is not an expert in these topics. On the other hand, almost 40% of the articles do not present any review to future investigations, fact remarkable. Related to the results and the test of algorithms (i.e., QA4 and QA5), we were satisfied with the conclusion of the evaluation, since all of the selected articles present results or they are tested.

Finally, in terms of QA6, we find that only an article does not describe the sanitary environment of application.

4 Discusion

In this section, we answer the research question defined in section 2.1 considering the knowledge assimilated from the set of articles. Note that the main objective is to know the current state of dynamic programming in the management in health centers, focusing on certain challenges launched by (D Gupta and Denton, 2008). Therefore, the analysis will divide this section into parts, each one corresponding to one of the research questions.

RQ1. Are there currently applications that use dynamic programming to help manage patients in the healthcare environment?

Despite intense research on software that supports dynamic appointment management in health environments, no article has been got in which the implantation of this technique in a real sanitary environment is reflected.

RQ2. Are the patient's preferences taken into account when making an appointment?

A fundamental idea, launched by (D Gupta and Denton 2008). It is a factor that should not be neglected because it directly affects the probability of cancelling an appointment or being delayed. This relationship is completely logical. If the patient's preferences are not taken into account, the patient can lose the interest in the appointment, favouring delays or forgetfulness.

However, few articles discuss this subject. Only three articles of the eight contemplated, mention the preferences of the patient, two theoretically and one experimentally. This may be due, as mentioned (Liu, Ziya, and Kulkarni 2010), to the difficulty to design models that take into account the needs of patients, obtaining complex mathematical models. In addition, in his experimental study, he concludes that such models have an arduous computation, despite being able to make a model in which the patient is presented with a set of possibilities in which to put only his appointment. That is, from my point of view, the preferences of the patient are not being considered in the model, e.g., to contemplate their working hours. In these studies, the system gives to the patient a set of optional days to choose which one is preferred.

Therefore, we should continue to investigate and research on how to keep patient preferences in the model.

Finally, it should be emphasized that none of the three articles say that contemplating these priorities can produce penalties in the function to be optimized. It's just a design challenge.

RQ3. What health environments have been implemented dynamic programming in managing of appointments? Differences to keep in mind?

Practically all studies have been done in all possible health areas: outpatient clinics, external consultations, nursing, treatment and surgery. We have not found articles that have tried to simulate the operation of a hospital. It is logical because is easier to start reproducing smaller environments.

In Figure 5 we show the distribution of articles by area of application.

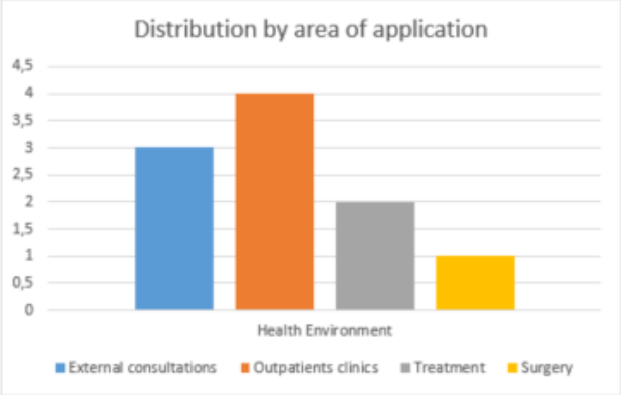

Figure 5. *Distribution by area of application*

It is not surprising that the sum of each block shown in Figure 6 illustrates more than eight articles because several articles dealt with more than one application domain. Studying this graphic we discerned that we find more articles related to the Ambulatory environment, followed closely by the External Consultations since both domains are similar.

On the contrary, Surgery and Treatment are environments more hostile. More characteristics that are vital must be taken into account in the other domains. For example, for

treatments, we include the articles (Gocgun and Puterman, 2014; Saur *et al.*, 2012), which are intended to manage appointments for the treatment of chemotherapy and radiotherapy respectively. In this scenario, times are essential to ensure the best saving percentage. Without forgetting the urgencies. Moreover, cancellations and delays have a great impact on time and, significantly, on costs because they are expensive treatments.

About surgery, thanks to one of our basic articles (D Gupta and Denton, 2008), we know the difficulty to model an appointment management system for that environment. The main impediment is the impossibility of generalizing the operating times. Not all bodies are the same, is possible to appear complications in the surgery, and not all surgeons operate at the same speed. Of course, without forgetting the emergencies. The emergencies are vital so we should minimize the waiting time of them, without neglecting or disfavouring the rest of the patients.

Therefore, although all are domains of the health world and the properties to contemplate are similar, when designing them it is essential to obtain close appointments, not very far in time, and it is indispensable to quickly manage urgencies.

RQ4. How to mitigate the effects of cancellations and non-presentations of patients?

About the possible cancellation or non-presentation of the patient, we show in Figure 6 the attribute of the schema definition designed in Section 2.5, with the values obtained for the set of articles formed.

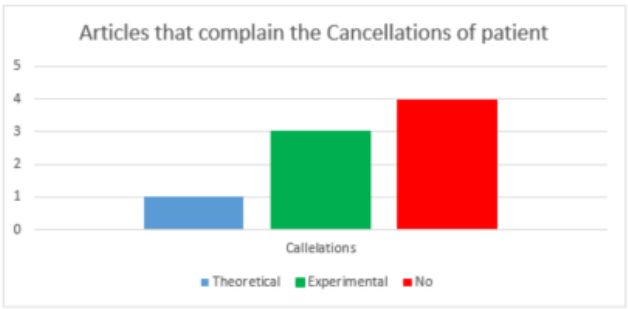

Figure 6. *Articles that complain in the Cancellations of patient*

Note that half of the selected articles (four) do not contemplate the possible cancellations, a very common fact and for which the dynamic scheduling of appointments would be a great help. If a patient cancels his appointment, and we have a dynamic appointment manager, that gap will be reused efficiently.

The experimental study (Liu, Ziya, and Kulkarni 2010) reinforces the idea of the close relationship between the time from the request of the appointment to the date of the appointment, and the probability of cancellation or absence. However, the three articles that account for cancellations (Gocgun and Puterman 2014, Laganga and Lawrence 2007, Liu, Ziya, and Kulkarni 2010) coincide in the following: if we try to minimize the probability of cancellation, paradoxically the time increases. Therefore, the experimental studies presented are conclusive.

RQ5. Is the time between the request of the appointment and the day of the appointment (indirect time) taken into account?

In the one hand, only (Liu, Ziya, and Kulkarni 2010) performs experimental tests trying to minimize the time between the day that the patient asked for an appointment, and the date of the appointment. This topic is already mentioned in the previous section because of its intimate relationship with cancellations. However, as discussed above, nothing clear can be discerned from this study.

On the other hand, (D Gupta and Denton 2008) claims to investigate the reason for such cancellations or absences.

RQ6. How to manage emergencies and their priorities?

It is an essential aspect in the sanitary domains and it is difficult to model. In Figure 7 we show a comparison of both properties, urgencies and its prioritization, looking to observe how many of the selected articles perform experimental tests contemplating emergencies and also prioritization.

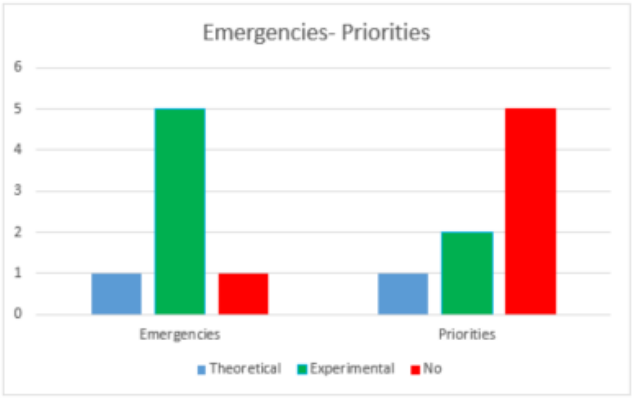

Figure 7. *Emergencies – Priorities*

Although five of the articles selected, out of a total of eight, perform experimental tests attending urgencies, only two of them consider their prioritization.

However, such studies warn of the complexity of modelling a dynamic appointment management system that accepts urgency. (Caylani, Veral, and Rosen 2006, Gurgun and Puterman 2014, Diwakar Gupta and Lei 2008, Laganga and Lawrence 2007, Saur et al., 2012) save certain time zones to be used for emergencies. However, if these are not used, it is a waste of time, with its consequent influence on costs. In addition, such time reservation increases the time lag between the day that the patient asked for an appointment and the day of the provided appointment which is an undesirable fact. Therefore, it is necessary to keep on researching.

5 Conclusions and future work

After performing the analysis, we highlight the key points to take into account to model an appointment management system for a health environment.

The main point is to know the characteristics of the sanitary environment that we wish to model. In this systematic review of the literature, we have found modeling about outpatient centers, outpatient consultations, treatments and surgery. Among them, they present great differences that have to be considered for a correct modeling of their appointment's manager. In short, the challenges of the health center, as well as its objective, must be clear.

For example, the goal of an outpatient may be to plan the maximum possible number appointments in the day (always on a minimum quality of care). A cancellation per day in this environment may not have much influence on costs.

However, if we move to the management of chemotherapy appointments, the indirect waiting time of the patient (time it takes from the date that a patient requests for an appointment until the date of the appointment) begins to become vitally important, since the percentage of salvation depends on it. In addition, cancellations in such expensive treatments are costly.

As already noted (D Gupta and Denton 2008), the indirect waiting time and the probability of cancellation or non-presentation of the patient are closely related. However, after this study, we have not found any methodology to follow to solve this problem. For example, if we try to decrease the probability of cancellations, paradoxically the indirect waiting time increases according to (Gocgun and Puterman 2014, Laganga and Lawrence 2007, Liu, Ziya, and Kulkarni 2010).

As future work, it could be interesting to carry out an analysis of the cancellations and non-presentations main causes, in order to better address the problem.

About patient preferences as a method to reduce the probability of cancellation or non-presentation of the patient, its modeling and its execution are complex. However, we believe that it should continue to be a line of future research. One line of research could be the restructuring of the management of appointments depending on the social actor who requests it. For example, preventing that retired people collapse the earliest appointments in the morning, when they may be the most accessible for workers. A study of such strategies would be desirable to see if they would improve the probability of cancellations and forgetting.

In short, we must continue to investigate new ways to avoid cancellations and non-presentations by patients, always keeping in mind their close relationship with the indirect waiting time.

Other key pillars in modeling any appointment manager for a health care environment are urgencies and their prioritization. In this regard, we must continue to investigate since the solution proposed by Caylani, Veral, and Rosen 2006, Gurgun and Puterman 2014, Diwakar Gupta and Law 2008, Laganga and Lawrence 2007, Saur et al. Al., 2012) not used the full potential of dynamic programming. After all, they are recovering time gaps for possible emergencies, and if they are not used, we will lose that time.

Despite the problems still present, decision-making techniques are fully applicable in health domains. Although the results indicate that the current state of technology is on the right way, there is still a long way to obtain reliable software.

In fact, nowadays many clinics continue to manage their appointments under the supervision of a person, without any support at all. So, it is necessary to emphasize that this technology is not being developed to supplant people, only to help them. As stated, this is a domain in which the mistakes are paid expensive, so it would be helpful to have a software that calculates the most optimal appointment for the patient who requests it, without losing the person in charge of full control of the schedule. That is, health professionals should not view this technique as a threat because is only a support for them. So, we must continue working on improving this technique, as well as giving visibility to its advantages in the health world.

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