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Identification of the Patient Requirements Using Lean Six Sigma and Data Mining

K. Khlie*, A. Abouabdellah

Industrial Engineering Laboratory, Modelling and Optimization of Industrial and Logistical Systems (MOSIL), ENSA, Ibn Tofail University, Kenitra, Morocco

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ABSTRACT

Lean health care is one of new managing approaches putting the patient at the core of each change. Lean construction is based on visualization for understanding and prioritizing imporvments. By using only visualization techniques, so much important information could be missed. In order to prioritize and select improvements, it's essential to integrate new analysis tools to achieve a good understanding of what the value is for the patient, analyze their requirements/expectations/needs and prioritize them in light of strong evidences and detailed measures. In that perspective, this paper intends to integrate lean thinking, data mining and six sigma improvement process methods with the goal to develop a lean health care driving methodology. The proposed methodology allows a better understanding of the patient perception of quality based on a Kano questionnaire. Questionnaire results are then analyzed using data mining tools to extract useful information. Finally, six sigma approach is followed to improve the quality of health care services and maximize the patient satisfaction. The main outcome of the study is that the first priority concerns the availability of physicians and health products, followed by the reduction of waiting time and minimization of errors related to prescriptions and diagnostics. The use of the six sigma approach on the medication circuit allows improving those three criteria.

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1. INTRODUCTION

Today's challenging health care sector requires the use of new management approaches that place the patient at the core of each change. Satisfying the patient requires a good understanding of its requirements and expectations. The principal question is about the comprehension of the manner the quality is perceived among patients. For that, we interrogate patients on the importance that they attribute to different quality features in health care. Based on Kano model, this study aims to identify the most important quality attributes and classifies them according to the patient point of view. Oriented toward maximizing patient satisfaction, the six sigma approach is used to empower and improve the perceived quality. The prioritization of attributes is essential to improve the quality of care since it helps to improve the operational performance and guides the development phase of the improvement plans and assists even decision making of health care reforms. This paper is structured as follows: the first part represents the background of our study in the health care sector. The second section shows the interest of combining the three concepts (lean, six sigma and data mining). The third part represents the integrated methodology. Results are then discussed and conclusions are drawn.

*Corresponding Author's Email: *k.khaoula40@gmail.com* (K. Khlie)

2. Background of the Study

2. 1. Lean and Data Mining In recent years, health care places high importance on services quality, which is recognized as the key determinant of patient's satisfaction. Under constraints of limited resources, the health care sector requires a good governance of existing means to ensure a high quality of care [1]. Lean approach is used in that context with the aim of reducing every activity that adds no value to the patient. The first step of every lean methodology is to identify what is the value in the eye of the patient and what is necessary to create it [2]. A good determination of the patient needs is one of the cornerstones of success for a

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lean methodology. Therefore, the value should be determined in a fairly high level [2]. The Kano model is one of the most powerful tools of lean that helps to identify the patient needs. It's used to understand the relationship between quality features/attributes and patient satisfaction [3]. Research in the area of health care quality considers the patient-oriented service as a fundamental factor when establishing quality monitoring programs and sustainable strategies in health care [4]. The aim of this study is to identify the key drivers and provide guidance for enhancing quality of service using the Kano model. Previous research integrates Kano with other quality management instruments to impressive qualities of health care services as QFD (quality Function Development) [5] in order to translate results into regular services planning [6], FMEA (Failure Mode and Effects Analysis) [7], CKM (costumer knowledge management) [8]. Our paper proposes an integrated methodology gathering the Kano model and data mining techniques to a better understanding of the patient needs.

2. 2. Lean and Six Sigma Lean thinking provides a total system approach and best practices but with poor analytic tools for diagnostic and improvement structures. On the other hand, six sigma offers a structured approach for improvement and powerful measurement and analysis tools with less focus on the creation of flows. Table1 gives detailed comparisons between lean and six sigma.

The development of a new methodology integrating both lean principles and six sigma approach allows identifying the priority problem and selects the best way and tools to address it.

3. MATERIALS AND METHODS

A Kano model-based questionnaire is used in a Moroccan public hospital. A total of 53 patients were questioned.

TABLE 1. Comparison between lean and six sigma

	Lean	Six sigma
Goal	Reduces waste	Reduces variability, improves the process capability
Project selection	Based on the value stream mapping	Based on statistics and strong analysis tools
Hierarchical level	Strategic relevance	Operational level
Length of projects	1 week to 3 months	3 to 6 months
Work teams	Involving all stakeholders	Teams guided by black and green belts resources
Vision	Systemic vison	Focus on the process on hand

The distribution of the sample is described in Table 2. The results were analyzed using data mining techniques. Satisfaction and dissatisfaction coefficients were calculated and the impact of personal criteria (age, gender, scholar level and salary) on patient requirements was studied.

3. 1. Presentation of the Kano Model In the past, customer satisfaction was seen as a *one dimensional construction* [3]: The higher the quality of the attribute, the higher the customer's satisfaction and vice versa. This way of thinking changed with the introduction of Kano's theory of attractive quality [9]: The relationship between the objective performance and customer satisfaction of a service attribute depends on how customers evaluate the service [9, 10]. This theory divides service attributes into five distinct categories:

- Must be attributes (Basic): Customers take them for granted when they are fulfilled; if they are not fulfilled they may become very dissatisfied.
- One dimensional attributes (Performance): Result in customer satisfaction when fulfilled and dissatisfaction when not fulfilled.
- Attractive attributes (Excitement): Absence does not cause dissatisfaction, but achievement can lead to customer delight.
- Indifferent attributes: Absence and presence are alike and does not cause dis/satisfaction.
- Reverse attributes: Result in customer dissatisfaction when fulfilled and satisfaction when not fulfilled.

TABLE 2. Participant characteristics

Characteristic	%
Revenue	
<2000dh	57
2000-5000dh	13
5000-9000dh	19
>9000dh	11
Education	
Bac-	28
Bac+1/bac+2	15
Bac+3/bac+4	23
Bac+5 & more	34
Gender	
Female	49
Male	51
Age	
< 24	23.6
25 to 44	38.7
45 to 59	38.7
60+	2

The Kano model explains that the relationship between customer satisfaction and performance of a service differs between the five categories [11]. Figure 1 provides a schema synthesizing all forms of customer requirements.

3. 2. Application of the Kano Method The questionnaire aims to identify the patient perception of quality attributes. A pair of question is formulated for each quality attribute. The patient has the possibility to evaluate the question by one of the five following options: I like it that way, It must be that way, I'm neutral, I can deal with it or I dislike it that way.

A recent study in health care quality attributes divides them into seven dimensions [12]:

- Tangibility (physical facilities, equipment and appearance of personnel)
- Reliability (ability to perform the expected service dependably and accurately)
- Responsiveness (willingness to provide prompt service)
- Assurance (courtesy displayed by staff and their ability to inspire trust and confidence)
- Empathy (caring, individualized attention provided to patients by physicians and staff)
- Core medical services (the central medical aspects of the service)
-Professionalism/Competence.

The survey questionnaire we used consists of 60 questions in which 8 are open questions. Questions are integrated into four sections containing all quality dimensions mentioned above:

- Administrative services (Mode of payment, administrative procedures)
- Staff (Expertise and empathy factors)
- Physical factors (order, property, calm, availability of health products, tranquility)
- External factors (location, type of sector, prices).

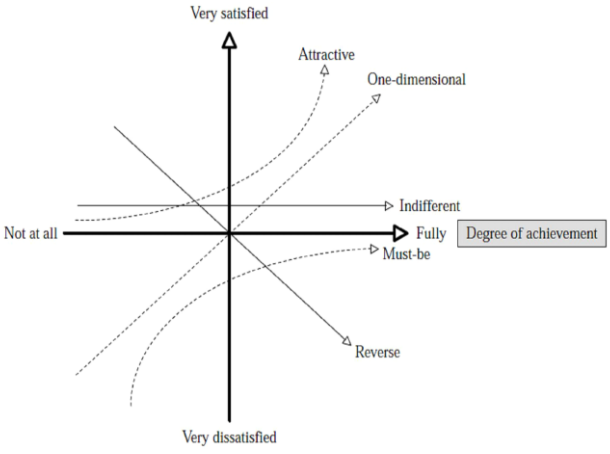

Figure 1. Kano model [11]

The majority of attributes that are used for evaluating health care services concern staff. Professional credibility, competence and communication are significant factors for patients in the evaluation of service [13]. Physician reputation, honesty, personal attitude, courtesy of staff, careful listening of patient's problems by the physician are also seen as important factors which can influence the patient's perception of service quality [12]. Table 3 summarizes all quality attributes of the questionnaire for the evaluation of public health care services classified into the seven dimensions of quality [12].

3. 3. Data Mining in Health Care The health care sector generates a very huge data which still unusable. Therefore, there is a need of a powerful process to extract important information from this huge data. This process is KDD (Knowledge Discovery in Databases). Data mining is a particular step in this process that is defined as "the application of specific algorithms for extracting patterns from a set of data for prospect applications using a measure [14]. KDD is the overall process including the selection of transformation of data and also the evaluation and interpretation of data mining results. Data mining allows extracting implicit, previously unknown, and potentially useful information from data [15].

Lean is a very useful approach for processes re engineering, it allows the improvement of productivity and the efficiency of material flows within complex systems [16, 17] but it suffers from problems in data collection and poor measures of performance [10]. A good understanding of data is necessary to be able to better understand patient preferences and needs and better respond to them. In that context, clustering is used to identify clusters of patients based on their empowerment degree among cancer patients [18], or their health state among patients with ventricular arrhythmia [19].

Over-the-counter health care products were also been clustered based on their temporal trends and also studied in order to detect certain outbreaks of diseases [20] and act rashly to determine the adequate treatment and to eliminate its causes. Data mining is also introduced to improve recruitment process into clinical trials [21] to diagnose heart diseases [22] or even to prevent, diagnose and treat the diseases at the genomic level [23]. Data mining techniques were also used for health care processes quality improvement in the area of prediction, real time control of defects [24], and treatment of causes and effects of processes defects identified by lean tools based on a statistical batch based decision tree learning [25]. All those researches show the importance of data mining in quality improvement within the health care sector.

TABLE 3. Quality dimensions and attributes of the questionnaire

Quality dimension	Attributes
Tangibility	Calm and tranquillity
	Appealing materials such as brochures, magazines, newspapers, etc
	Professional appearance / dress of the staff
	Improvement of appointment made ways (on site into by phone)
	Property and order
	Quality and quantity of food
Reliability	Carful diagnosis of the patient's problems
	Technology of devices
	Correct diagnosis from the first time
	Maintaining accurate and neat records of the patient's medical history
	Devices availability
	Prescription of efficient, reliable and affordable medicines
	Physician's reputation
	Physician compliance with latest findings
	Consistency of fees and other charges
	Medical errors
Responsiveness	Closer appointments
	Delivery of services at the time promised
	Waiting time to receive service
	Prompt service without appointment
	Gap between time of getting an appointment and the appointment
	Availability of prescribed medicines at the pharmacy
Assurance	Courteous and friendly staff
	Confidentiality of patient's information
	Ability of staff to inspire trust and confidence
	Thoroughness of explanation of medical condition and treatment
	Physicians making patients feel safe and relaxed in their transactions
Empathy	Honesty of physician
	Personal demeanour
	Taking time to listen
	Patience
Core Medical Services	Availability of physicians
	Duration of consultations
Professionalism/Skills / Competence	Qualified, skilled staff
	Highly experienced staff
	familiarity with latest advances in medical field
General Characteristics	Flexibility of admissions treatment procedures
	Payment facilities and medical conventions
	Schedule of visits
	Hospital reputation
	Hospital rates
	Hospital location

By gathering lean health care principles and data mining techniques in a unique continuous improvement methodology, we're about to gather operational efficiency and well-founded managerial decisions.
Our objectives are:
- Classification of features into three categories: this classification is done based on frequencies of each type of response category for all questions.
- Calculation of satisfaction and dissatisfaction coefficients: the satisfaction coefficient is calculated by adding attractive to one dimensional attributes and dividing by the total of the four categories. The dissatisfaction coefficient is calculated by adding must-be to one dimensional attributes and dividing by the total of the four categories.

4. DATA ANALYSIS

Among the answers given by patients concerning what could really make them satisfied, courteous staff is one of the most cited. Some patients express their dissatisfaction and believe that the only thing that could satisfy them in a public hospital is "leaving the hospital". Figure 2 summarizes the perception of patients to some attributes. The most important quality attributes to patients are:

- Availability: availability of physicians and health products.
- Timeliness of response: patients express their desire to reduce waiting times.
- Safety: minimization of errors related to prescriptions and diagnostics.

Each of these significant attributes will be discussed in what follows.

- Availability:

The availability of physicians and medicines in the hospital is the first requirement of patients. They believe that the main cause of the unavailability of physicians is their unnecessary moves.

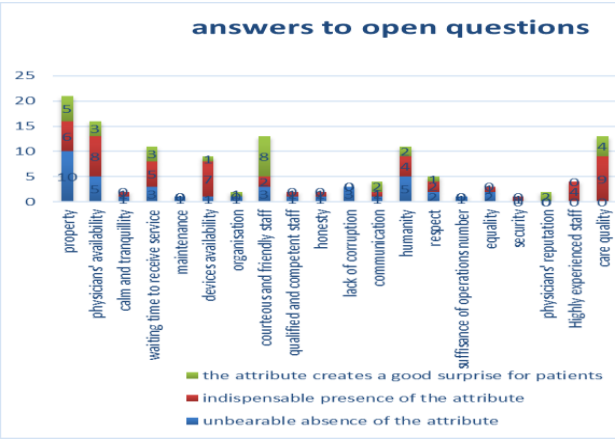

Figure 2. Indispensable and unbearable attributes

According to patients, unnecessary moves is about 56%. Availability is the reason why 55% of patients always prefer private hospitals, while 36% prefer it in some cases. For more than 21% of patients, prescribed medicines were out of stock. Medicines shortages affect health system finances by increasing the cost of delivering patient care. It also creates a high level of frustration for everyone involved, including purchasing agents, pharmacists, nurses, physicians, and patients [26].

- Safety:

Patients express their dissatisfaction concerning repetitive errors made by health care professionals especially those related to the medication circuit because of their high level of criticality. In fact, prescription, dispensation and administration errors may have serious consequences such as serious injuries, disability, or death. A proper planning of medicines supply is required to minimize adverse effects on patient care and maximize its safety. According to the results of the questionnaire, 55% of patients never tolerate medical errors, and 43% tolerate them sometimes.

- Waiting time:

Waiting time is also an important attribute for patients. The average time of waiting from which it becomes unbearable is 65 minutes. Responses are distributed between 4 hours and 15 minutes. In average, the optimal waiting time is 25 minutes. Responses are distributed between 5 minutes and 2 hours. Figure 3 summarizes the answers of patients.

According to the patients' perception, the quality attributes chosen are classified into three categories based on their priority rate as presented in Table 4.

The priority rate is defined as the number of persons that consider it as Obligatory, Attractive or Proportional divided by the number of persons that are indifferent to its presence or consider it with an opposite counter.

- Impact of personal data on the requirement degree of patients:

By clustering patient according to their degree of requirement, results show that the requirement degree is proportional to the level of studies and inversely proportional to age. Revenue and gender do not impact it.

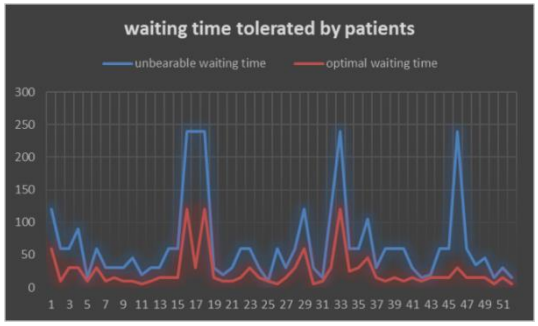

Figure3. Optimal and unbearable waiting time

TABLE 4. Quality attributes categories

Categories	Quality attributes
Very important	Elimination of medical errors
	Availability of physicians
	Waiting time reduction
	Availability of prescribed medicines at the HP
	Availability of medical equipment
	Closer appointments
Less important	Property
	Equipment technology
	Comfort
	Familiarity with latest advances
	Physicians' appearance
	courtesy
Not important at all	Equipment attractiveness
	Physicians' experience
	Schedule of visits
	Flexibility of admissions procedures
	Consultation duration

5. SIX SIGMA FOR QUALITY IMPROVEMENT

This part uses six sigma improvement process tools within the medication circuit in the hospital with the aim of reducing waiting times for both patients and physicians, increasing the availability of physicians and health products and minimizing medical errors.

Medication errors could occur during any of the four steps of the medication circuit: from prescription, dispensation, passing through administration until the follow-up and review step. The reduction of errors is the key for the patient safety and minimization of costs. For that, our study aims to reduce medical errors that occur in the medication circuit using the DMAIC methodology. It is composed of five main steps. Each letter of the acronym D.M.A.I.C represents the initial of the principal function of the correspondent step.

D. Define: this step consists of the definition of the perimeter of the problem, the expected results, the required resources and any other details.

M. Measure: in this step, data is collected, the performance and its evaluation are measured and the priorities to improve are identified.

A. Analyze: this step aims to understand the problem, use analytic and statistical tools to identify its causes.

I. Improve: choosing the most appropriate way to improve and implement it are the objectives of this step.

C. Control: this step is the most important and the most difficult of all. Very few six sigma projects reach

this step. It consists of maintaining the results and ensuring continuous improvements in order to further improve and avoid backwards.

5. 1. Definition of the Perimeter of the Study The measurement process will be limited to the medication circuit. For that, it would be useful to start with a simple modeling of this circuit. It is composed of four main steps as summarized in Figure 4.

5. 2. Measurement:

5. 2. 1. Errors Epidemiology According to a study conducted within a hospital center, potential errors of the prescription step are [27]:

- ✓ Deficiencies in terms of medicinal knowledge (64%)
- ✓ Lack of knowledge about the patient (15%)
- ✓ Mental slip (9%)
- ✓ Transcription (5%)

In what concerns the dispensation step, there are four main errors, as follows [28]:

- ✓ Label errors (80%)
- ✓ Inappropriate quantity (7%)
- ✓ False medication (6%)
- ✓ False dose (6%)

The majority of errors notifications are issued from administration step. It results essentially from two main causes [29]:

- ✓ Injection of the inappropriate drug (69%)
- ✓ Injection of an incorrect dose (26%).

In the last step of the medication circuit, there are three potential risks:

- ✓ Lack of identification of the cause of the error resulting in a difficulty to resolve it.
- ✓ Inappropriate surveillance (periodicity, material)
- ✓ lack of traceability of the expected effects and medicinal errors.

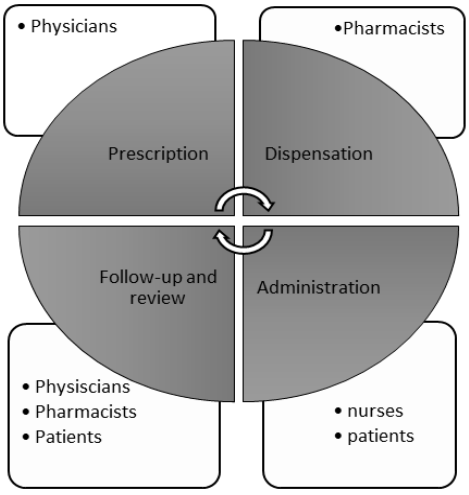

Figure 4. Drugs circuit at the hospital

In order to understand the repartition of errors during the medication circuit in a hospital, patient, health care professionals including physicians, nurses and pharmacists were interviewed about the frequency of errors in each step of the circuit. Table 5 represents the results of percentages given by those stakeholders concerning errors in each step of the circuit.

5. 2. 2. Calculation of the Sigma Level In the main of correcting errors of the medication circuit and improving its capability, it's necessary to measure the sigma level. The six sigma method uses the ratio between the number of medical errors and the number of medical errors opportunities. This ratio is defined as follows:

The ratio of Medical Errors (EM)= number of ME/ number of ME opportunities. This ratio allows the calculation of the sigma level of the medication circuit at the hospital.

The hospital in question counts about 360 medical errors per year. Based on the percentages of errors (per step of the medication circuit) given in Table 5, we count 128.41 prescription errors, 52.81 dispensation errors, 130.79 administration errors and 47.99 follow-up and review errors. Those values represent the numerators of the sigma level. For the denominators, it's necessary to calculate the number of medical errors opportunities. In 2015, the hospital counted 16 332 hospitalized patients. The average length of stay is 13.02 days [30]. According to an investigation on the prescription and utilization of drugs in Morocco, the average number of prescribed medications per ordinance is 3.27. This number corresponds to the impression of the majority of physicians (62.9%) for whom the number of necessary medication per patient is 3 [31]. The number of prescription medical errors is calculated according to the following formula:

Number of opportunities of ME in prescription= number of potential types of errors * number of admissions* average number of orders per patient making a total of 130 656 (2*4*16 332).

For the dispensation step, the number of opportunities is the product of the average number of orders per patient, the number of potential types of errors during the dispensation and the number of admissions making a total of 130 656 (2*4*77047)

TABLE 5. Percentages of medical errors of the four steps of the medication circuit

	Presc-ription	Dispen-sation	Adminis-tration	Follow-up
Patients	32	10	42	16
Health care professionals	39	12	37	12
Managers	36	22	30	12
Mean	35.67	14.67	36.33	13.33

In the administration step, the average number of administrations per patient is 4 times per day. The number of opportunities is calculated as follows: the number of administrations per day per patient* average length of stay* number of admissions*number of potential types of administration errors making a total of 5103423.4 (4*3*13.02*16 332*2).

For the last step, the number of opportunities is the product of admissions* number of potential errors of the follow-up and review step making a total of 48996 (3*16 332). Table 6 summarizes the results of ME, opportunities of ME, the ratio of ME and the sigma level for each step of the medication circuit.

5. 3. Analysis Even if the administration step has the biggest number of errors, it has the best sigma level. That's because the number of opportunities of ME in this step is very high. The sigma levels of the prescription and follow-up steps are the lowest and more efforts must be done in this area to improve them. The average sigma level of the medication circuit is 4.91. A secure medication circuit ensures that the right patient will receive the right medication at the right route with the right dose at the right moment.

In the measurement step, we identified several forms of errors that occur the most during the medication circuit. Some of the main causes of those errors are:

- ✓ Lack of respect of laws and standards,
- ✓ The blame culture causing significant harm on the system improvement and prevention of future errors.
- ✓ Lack of resources made available to the health care professionals.
- ✓ Lack of communication between the hospital entities.
- ✓ Excessive confidence on health care professionals and patient's physical state.

The following step proposes solutions to minimize ME and outlines the results of their implementation.

5. 4. Improvement and Control In the literature, several procedures and tools exist for the securement of the medication circuit. Results of research data that are specifically related to the implementation of those procedures are very satisfactory.

TABLE 6. Sigma levels for the medication circuit's steps

	Presc-ription	Dispen-sation	Adminis-tration	Follow-up
ME	128.41	52.81	130.79	47.99
ME opportunities	130656	130656	5103423.4	48996
Ratio of ME	982.8	404.2	25.6	979.5
Sigma level	4.59	4.87	5.58	4.6

The use of barcode readers is one of the most effective methods [32]. In fact, the administration of drugs must be assisted by the reading by barcode at the patient's bedside reduces 67% of dispensation errors, 51% of administration errors and 100% of follow-up errors. The use of lean maintenance improves the reliability of medical equipment and greatly reduces waiting times [33].

The computerization of prescriptions reduces 55% of prescriptions errors. The labeling of preparations is also considered as one of the most important tools to minimize prescription administration errors especially those due to the preparation of doses to administrate. The standardization of labeling and preparation of medication allows avoiding several types of preparation errors. It's also advised to involve effectively the patient into the improvement approach in order to increase its security and improve its satisfaction. Placing pharmacists into health care services is also considered as an important initiative to take in order to minimize prescription errors.

By the introduction of computerized prescriptions and barcodes readers, the sigma level will be vastly improved. Table 7 summarizes the new sigma levels after the implementation of computerized prescriptions and barcodes readers.

The new average sigma level of the medication circuit is 5.475. That results are an increase of 0.565. The new sigma level corresponds to 40 ME per million. Compared to 386 medical errors per million (sigma level=4.91), those improvements will allow a reduction of 346 medical errors per million.

6. CONCLUSION

Lean health care is a fundamental approach to minimize non added value activities. It's important to patients only if it's based on a well-founded study of their requirements and priorities. Data mining techniques are very useful in questionnaire results analysis. It allows us understand what patients need from public hospitals and how they perceive health care quality attributes.

Lean efforts must be focused on the very important category of quality attributes to meet patient requirements. Among the most important ones are the safety of the patient, the availability of physicians and medicines and finally the reduction of waiting times.

TABLE 7. Sigma levels after the improvements

	Presc-ription	Dispen-sation	Adminis-tration	Follow-up
Ratio of ME	442.3	133.4	12.54	0
Sigma level	4.84	5.24	5.82	6

The introduction of six sigma will bring more precise and very detailed measurements. Relying on the patient requirements -identified using the integration of lean and data mining- the six sigma allows a better understanding of the problems and barriers preventing from the achievement of the required quality, their causes and effects and it could be used as a basis and guide of the lean health care improvements.

The perspective of this work deals with the integration of more actors of the hospital system as the physicians, pharmacists, nurses and managers in the identification of the quality attributes in order to obtain an integrated model of quality that satisfy all the main stakeholders of the hospital.

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Identification of the Patient Requirements Using Lean Six Sigma and Data Mining

K. Khlie, A. Abouabdellah

Industrial Engineering Laboratory, Modelling and Optimization of Industrial and Logistical Systems (MOSIL), ENSA, Ibn Tofail University, Kenitra, Morocco

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چکیده

مراقبت‌های بهداشتی ناب یکی از رویکردهای مدیریت جدید است که بیمار را در هسته هر تغییر قرار می‌دهد. ساخت و ساز ناب بر اساس تجسم بصری برای درک و بهبود اولویت‌ها بنا نهاده شده است. با استفاده از تکنیک‌های تجسم به تنهایی، اطلاعات مهم بسیاری می تواند از دست رود. به منظور اولویت بندی و انتخاب بهبودها، لازم است ابزارهای تجزیه و تحلیل جدید ادغام شوند تا به درک خوبی از آنچه که برای بیماران باارزش است رسید، نیازمندیها/ انتظارات/ مطالبات آنها را آنالیز کرد و در پرتو شواهد قوی و اقدامات دقیق آنها را اولویت‌بندی کرد. در این دیدگاه، این مقاله در نظر دارد به ادغام تفکر ناب، داده‌کاوی و روش فرایند بهبود شش سیگما با هدف توسعه یک روش مراقبت بهداشتی ناب بپردازد. روش پیشنهادی اجازه می‌دهد تا درک بهتری از آگاهی بیمار از کیفیت بر اساس یک پرسشنامه کانو داشته باشیم. نتایج پرسشنامه‌ها پس از آن با استفاده از ابزار داده‌کاوی تجزیه و تحلیل می‌شود تا اطلاعات مفید استخراج شود. در نهایت، رویکرد شش سیگما به دنبال بهبود کیفیت خدمات مراقبت‌های بهداشتی و به حداکثر رساندن رضایت بیمار است. نتیجه اصلی پژوهش این است که اولویت اول مربوط به در دسترس بودن پزشکان و محصولات بهداشتی بوده، به دنبال آن کاهش زمان و به حداقل رساندن خطاهای مربوط به نسخه و تشخیص هستند. استفاده از رویکرد شش سیگما در سیکل درمانی اجازه می‌دهد تا این سه معیار بهبود یابند.

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