



MARMARA UNIVERSITY
INSTITUTE FOR GRADUATE STUDIES
IN PURE AND APPLIED SCIENCES



**PROCESS IMPROVEMENT THROUGH
DECISION MAKING BASED HYBRID
METHODOLOGIES AND A CASE STUDY**

ZEYNEP TUĞÇE KALENDER

Ph.D. THESIS

Department of Industrial Engineering

Thesis Supervisor

Prof. Dr. Özalp VAYVAY

ISTANBUL, 2020



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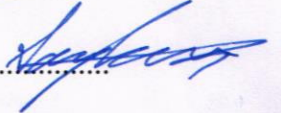
Zeynep Tuğçe KALENDER, a Doctor of Philosophy student of Marmara University Institute for Graduate Studies in Pure and Applied Sciences, defended her thesis entitled “**Process Improvement Through Decision Making Based Hybrid Methodologies and a Case Study**”, on January 03, 2020 and has been found to be satisfactory by the jury members.

Jury Members

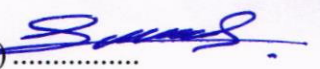
Prof. Dr. Özalp VAYVAY (Advisor)

Marmara University (SIGN) 

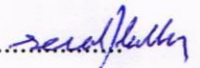
Prof. Dr. Bahar SENNAROĞLU (Jury Member)

Marmara University (SIGN) 

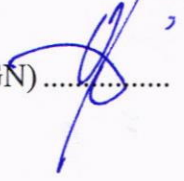
Prof. Dr. Hakan TOZAN (Jury Member)

Medipol University (SIGN) 

Doç. Dr. Serol BULKAN (Jury Member)

Marmara University (SIGN) 

Doç. Dr. Oğuzhan ERDİNÇ (Jury Member)

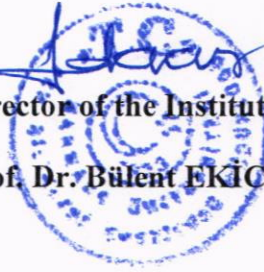
Bahçeşehir University (SIGN) 

APPROVAL

Marmara University Institute for Graduate Studies in Pure and Applied Sciences Executive Committee approves that Zeynep Tuğçe KALENDER be granted the degree of Doctor of Philosophy in Department of Industrial Engineering on 5.2.2020 (Resolution no: 2020/05-06).


Director of the Institute

Prof. Dr. Bülent EKİCİ



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ÖZET

KARAR VERME TABANLI HİBRİD METODOLOJİLER İLE SÜREÇ İYİLEŞTİRME VE BİR VAKA ÇALIŞMASI

Sağlık kalitesi ile ilgili endişeler yeni değildir; öte yandan günümüzde bu endişeler sağlık ve toplumdaki makro değişiklikler nedeniyle çok açık hale gelmiştir. Sağlık hizmetlerinin tüm düzeylerinin kalitenin önemi hakkında bir perspektifi vardır ve hastaneler kalite sorunları ışığında vizyonlarını da genişletmektedirler. Bu kapsamda, son yıllarda hasta güvenliği konusunda artan bir odaklanma ve bazı iyileşme göstergeleri vardır, ancak yine de 10 hastanın 1'inde advers bir olay gelişmektedir. Güvenlik ve kalitenin diğer boyutları arasındaki bağlantının değeri artık daha çok anlaşılmaktadır. Bununla birlikte, sağlık sisteminin analiz edilmesi oldukça zordur, çünkü sağlık sisteminin kendisi ve sistemi etkileyen faktörlerin her biri olasılıklı ve belirsizdir. Eksik bilgi durumu kaçınılmazdır ve bu yapı karar verme süreçlerinde de belirsizliğe neden olmaktadır. Bu nedenle, kapsamlı bir hasta güvenliği sisteminin geliştirilmesi karmaşık bir sorundur ve hibrit karar verme modellerinin kullanılmasını gerektirmektedir.

Bu çalışmada, mevcut durumu daha iyi değerlendirmek ve iyileştirme aşamaları için girdi oluşturmak amacıyla kapsamlı bir karar verme modeli önerilmiştir. Model tarafından oluşturulan endeks puanları, tıbbi hataları sınıflandıracak bir standart oluşturmak için kullanılmaktadır. Verilerin ve süreçlerin karmaşıklığının üstesinden gelmek için bulanık mantık yaklaşımları kullanılmıştır. Modelin geliştirilmesi tamamlandıktan sonra, seçilmiş özel bir hastanede uygulanmıştır ve böylece hâlihazırda meydana gelen tıbbi risklerin önceliklendirilmesi yapılmış, hasta güvenliği konusunda farkındalık artırılmış ve ilgili sağlık kurumunun mevcut durumu her gösterge bazında görüntülenmiştir.

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Zeynep Tuğçe KALENDER

ABSTRACT

PROCESS IMPROVEMENT THROUGH DECISION MAKING BASED HYBRID METHODOLOGIES AND A CASE STUDY

Concerns about healthcare quality are not new; however, nowadays these concerns have become so obvious due to the macro changes in healthcare and society. All levels of healthcare have a perspective about the importance of quality and hospitals are extended their vision in the light of quality issues. In this regard, there is an increased focus and some indications of improvement on patient safety issues in recent years however still 1 in 10 patients develop an adverse event. The connection between safety and other dimensions of quality is now more appreciated. However, analyzing the healthcare system is quite difficult since the healthcare system itself and each of the factors affecting the system is probabilistic and uncertain. The imperfect knowledge situation is inevitable and this structure is causing uncertainty in the decision-making processes. For that reason, the development of a comprehensive patient safety system is a complex problem and requires hybrid decision-making models.

In this study, a comprehensive decision-making model is proposed to better evaluate the current situation and create input for the improvement stages. Index scores that are generated by the model are used to create a standard in classifying medical errors. Fuzzy logic approaches are used to handle the complexity of the data and processes. After the development has been completed, the model has been applied in a selected private hospital, thereby medical risks that have already occurred are prioritized, awareness of patient safety has been increased and the current state of the relevant health institution is displayed on each indicator basis.

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CLAIM FOR ORIGINALITY

PROCESS IMPROVEMENT THROUGH DECISION MAKING BASED HYBRID METHODOLOGIES AND A CASE STUDY

In the past, providers of healthcare services merely focused on quality assurance, risk management and utilization from strict external standards but today, healthcare professionals have to become increasingly concerned about the development of broader measures. However, although health systems are more efficient, patients do not always receive the care that is most appropriate for them, and still, preventable adverse events occur. Current researches revealed that most of the medical errors caused by the system rather than individuals. For that reason, emphasis should place on the system of care not only to prevent errors but also to learn from error and built on a culture of safety. Recently, the implementation of several methodologies increased awareness and generated an impulse for multidisciplinary perspectives in healthcare. Nevertheless, each methodology has some drawbacks and this situation is emphasizing the need for a hybrid model.

Additionally, health institutions are held responsible for the establishment of safety reporting systems by regulations but each hospital generally carries out its own measures for patient safety. In most of them, medical errors are examined one by one, which is not only a time-consuming system but also highly human depended. The lack of a standard patient safety system causes a great variation in provided service quality among hospitals.

In this paper, a hybrid decision-making model is proposed to create a standard patient safety management model via considering severity, preventability, and frequency of each error. The underlying reason is providing the reliability of the measurement system before determining regulatory and preventive actions. As the number of patients continues the rise, the need for a system in which not only errors methodically reviewed but also prioritized to identify the most critical ones to used resources efficiently becomes vital.

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SYMBOLS

$\mu_A(x)$	: Membership degree to set A
$\nu_A(x)$	: Non-membership degree to set A
$\pi_A(x)$	: Hesitation degree
$S(\tilde{\alpha})$	: Score function
$H(\tilde{\alpha})$	: Accuracy function
$\tilde{\alpha}_i$	: Fuzzy set i
k_i	: Hesitancy of membership/non-membership set i
w_{j_i}	: Weight of indicator i
r_{ij}	: Decision maker's evaluation of i^{th} for j^{th} indicator
λ_i	: Weight of decision-maker i
$L(p)$	: Linguistic term set
$L^{(k)}$	: Linguistic term
$p^{(k)}$	: Probability of k^{th} linguistic term
$r^{(k)}$	: Subscript of the k^{th} linguistic term
$d(x, y)$	: Distance between x and y
$S(A, B)$	: Similarity between sets A and B
E	: Entropy

ABBREVIATIONS

AN	: Analytic Errors
BTH	: Care, Diagnosis and Treatment Process Related Errors
BYH	: Physical Structure Related Errors
CSH	: Device/Equipment/System Related Errors
FMEA	: Failure Mode and Effect Analysis
GIS	: Generalized Improved Score Function
HFLTS	: Hesitant Fuzzy Linguistic Term Sets
HRH	: Patient/ Attendant Related Errors
IFs	: Intuitionistic Fuzzy Sets
IFWA	: Intuitionistic Fuzzy Weighted Aggregation Operation
IIFWA	: Interval Valued Intuitionistic Fuzzy Weighted Aggregation Operation
ILH	: Communication Errors
IOM	: Institute of Medicine
IVIFs	: Interval Valued Intuitionistic Fuzzy Sets
KTH	: Errors Concerning the Transfusion of Blood and Blood Products
NIH	: Errors Regarding Nutrition
PLA	: Probabilistic Linguistic Averaging Operator
PLTS	: Probabilistic Linguistic Term Set
PLWA	: Probabilistic Linguistic Weighted Averaging Operator
PO	: Post Analytic Errors
PR	: Pre-Analytic Errors
RCA	: Root Cause Analysis
RPN	: Risk Priority Number
SIMPATIE	: Safety Improvements for Patients in Europe
TKH	: Medical Record and Clinic Evaluation Related Errors
TOPSIS	: Technique for Order of Preference by Similarity to Ideal Solution
TQM	: Total Quality Management
WHO	: World Health Organization
WP	: Weighted Product

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1. INTRODUCTION

Health processes differ from other systematic processes mostly because of huge variability in patients and circumstances, the need to adopt processes quickly with the rapidly changing knowledge base and the importance of highly trained professionals who must use expert judgment in dynamic settings. Moreover, increases in the complexity of diagnosis and treatment of patients and changes in patients' expectations, increases concerns day by day. From this point of view, healthcare systems throughout the world have undergone a significant change. At the end of 20th century, many reports revealed that there must be a change to achieve high quality levels of care with providing strong proof of evidence. These reports highlighted the quality deficiencies as never before and explained the need of change in terms of quality. In 2000, Institute of Medicine (IOM) published a report called "To Err is Human: Building a Safer Health System" which is considered as a milestone in patient safety. Report focused on patient safety and estimated that between 44,000 and 98,000 deaths from medical errors occurred annually in hospitals. Over half of these errors were determined to be avoidable; this would result not only in saved lives but also in an estimated financial savings of \$17-\$29 billion per year. Patient safety issues such as preventing mistakes connected policymakers, health providers and patients for the first time (IOM, 2000). Since 2005, World Health Organization (WHO) is organized a conference called "Global Patient Safety Challenges" and each year one of the main issues of patient safety is examined in detail. In the 3rd Global Patient Safety Challenges (World Health Organization, 2017), it is stated that worldwide awareness of patient safety is increasing day by day, revealing that the common point of applied and ongoing projects is the coordinated work of different units.

It is a well-known fact that the initial step reaching high performing health system in terms of patient safety is the standardized measurements, which can be used by clinicians to improve care for patients and by managers, governments and national agencies to increase quality and safety for patients. Today, according to regulations, safety-reporting systems should include medication, transfusion and surgical safety, patient falls etc. and the corrective and preventive actions should be taken for reported events however, the lack of standardized measurement and reporting mechanism causes vital problems in

understanding and identification of safety and quality issues. Moreover, differences in reporting standards and measures across states and territories or between private and public sectors, create difficulties in comparisons therefore restricts the ability of health systems to learn and evolve.

The demand of healthcare services is increasing nowadays under the situation with restricted resource. Many environmental and social reasons such as increased population, decreased financial resources, high expectations, competition and etc. directly affected the healthcare industry. In addition to all these, sharing of experience immediately as a result of technological developments, changing of other patients' views with these experience sharing and even researching on the internet without going to the health institution quickly change the dynamics of the healthcare sector. Concerns about the quality of healthcare is not new however these concerns have become manifest in recent times due to the changes in healthcare and society. Increases in the complexity of diagnosis and treatment of patients as well as change in patients' expectations, in combination with government concerns have combined to put healthcare foremost in the public mind. Therefore, no matter what the size, shape, location, mission or orientation of healthcare organization, they are all facing mix of the same problems.

1.1. Aim of the Study

In Turkey, quality improvement studies are started in 2003 in the context of Health Transformation Program and then standardization programs for hospitals are developed and pilot studies with several trainings are planned. Quality indicators for healthcare are determined within the scope of these quality improvement studies by the Ministry of Health and targets and quality indicators are detailed in order to reach optimum quality

level of in all hospitals with the "Quality Standards in Healthcare" study whose last version is published in 2016. Additionally, a "Classification system for patient safety errors" has been created by determining the error codes with the security reporting system and thus following up of errors are targeted. In 2017, classification systems are updated to make the error classes more detailed. Although the importance of patient safety issue realized long before, much of the road is not preceded. In Turkey, under the part 6 of the "Regulation on the Safety of Patients and Employees"; published by the Ministry of Health, the practices that healthcare establishments need to do about patient

safety are generally defined. In addition to these studies, the Ministry of Health has identified quality indicators in health within the scope of quality studies and has targeted error tracking by following error reporting with the developed security reporting system. However, each health institution can determine its own methods when planning with the purpose of patient safety and there is no standard in this regard even if it uses determined health indicators. Healthcare institutions can create their own internal regulations and follow-up plans on patient safety. While this is beneficial for the dissemination of patient safety cultures, it poses difficulties in terms of auditing and the lack of an effective, systematic and standardized work on this area is felt.

In this regard, firstly literature of quality management in healthcare is examined via conducting a general review to better understand the current efforts at the international level. Afterwards, literature is reviewed from patient safety perspective via focusing on patient safety studies published after 2000. However, milestone studies, which are published before 2000, are also examined to create better understanding of the quality evolution. Review reveals the urgent need for a standard patient safety system not only to measure the factors that threaten the safety but also make regulatory and preventive improvements via creating a safety culture.

Later, a comprehensive index system is proposed that is developed for achieving a standard patient safety management model by classifying medical errors that risks patients. It is planned that the index system will consist mainly of three dimensions, namely severity, preventability and frequency, and for the measurements, the interval valued intuitionistic fuzzy logic is used because of the complexity of the health structure and processes. In the analysis of the different characteristics of the data, also probabilistic linguistic terms sets are used in weight determination. In order to collect the data, an online evaluation form is applied for 5 month period (June 2018-October 2018). Evaluation form is sent not only the selected health institution but also sent to all levels of health employee especially to doctors and nurses. Totally, 134 answers are collected however 12 of them eliminated because of the missing data. Finally, 122 answers are collected from all levels of health employee and used in the study. As a result of this systematic study, present situation of the related health institution is displayed on each indicator basis and institutions are motivated to identify and prioritize future improvements. Analysis results that are conducted with the index system are used as an

input for the improvement stage and continuous improvement cycle will be created in terms of patient safety in the quality management of hospitals. Study is conducted in a private University Hospital in Istanbul, and it is presented as a reference model for hospital administrators and decision-makers of health policy by proposing a valid and objective method for measuring patient safety. Study not only provides a starting point for those interested in patient safety via proposing a conceptual safety management model but also tries to answer one of the common question, the importance of quality efforts and their direct affects in health systems. Additionally, it is aimed to create better understanding among healthcare teams in order to increase the quality culture and improve safety of patients.

1.2. Literature Review

In this part, firstly literature of quality management in healthcare is examined via conducting a general review to better understand the current efforts at the international level. Afterwards, literature is reviewed from patient safety perspective via focusing on patient safety management studies published after 2000. However, milestone studies, which are published before 2000, are also examined to create better understanding of the quality evolution.

1.2.1. Quality management in healthcare

In the past century, the logic of companies depended on the providing final products -as much as possible- and having a high profit due to the limited competition. Nowadays, globalization changed the whole business environment structure. The power that manufacturer used to have has passed to the customer. From this point of view, international competition in the business environment has been brought to the peak level.

Ever since the industrial world began to experience tough global competition, companies have to create customer focused management system to survive among rivals. The basic principle to create a customer-focused system is becoming a flexible company that can integrate recent technology to its own processes and apply a high quality level for customers. However generally it is not possible to define quality with a single meaning that includes the common views. The definition of quality changed through time according to circumstances and gain new dimensions continuously. The difficulty in defining quality in service sector is to translate future needs of the user into measurable

characteristics. Parasuraman et. al. (1985) suggested that service quality can be explained as the difference between predicted (customer expectations) and perceived service (customer perceptions). It is a well-known fact that service quality is hard for the consumer as well in terms of evaluating the service quality rather than goods quality. In the healthcare industry, which is one of the main pillars of service sector, the subject even more relevant in customer/patient perceptions and because of this, the method of providing a competitive advantage is important in carrying improved healthcare services to the highest possible quality level.

Quality measurement in healthcare is more difficult to define than other services because it is the customer himself/herself and the quality of his/her life that is being evaluated. Effective monitoring of patient care quality must begin with complete understanding of who the customers are. As the industry changes the role that patients play in defining what quality means has become a critical competitive consideration. A widely accepted definition of quality, as given by the IOM is (Lohr, 1990);

“...Quality of care is the degree to which health services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge...How care is provided should reflect appropriate use of the most current knowledge about scientific, clinical, technical, interpersonal, manual, cognitive and organization and management elements of healthcare”

Healthcare services have a unique position among other services due to its very nature of the highly involved risks. In other words, as hospitals deal with human life and health, they are different from the other industries. Healthcare system can be summarized as the management of treatment of any health problem through the services that might be provided by medical nursing or any other relating health institutions (Lee et. al., 2015). Hospitals must constantly understand the needs of the patients and provide all the health services needed in order to attract them. In other terms, healthcare delivery is a patient oriented service industry for that reason hospitals are not only required to provide medical care but also expected to address the issue of improving customer satisfaction. This makes measuring customer satisfaction and service quality in a healthcare setting more important and simultaneously more complex. In healthcare systems, there is only one aim: to increase the percentage of the healthy population

however, human involvement in the process and the intangibility of the resulting product make it difficult to standardize and control healthcare.

In the past, providers of healthcare services merely focused on quality assurance, risk management and utilization from strict external standards but today, healthcare professionals have to become increasingly concerned about the development of broader measures such as integrated patient care, financial, human resources and cost control. Wadhwa (2010) categorized these factors as it is presented in the Figure 1.1. into two sub categories; factors that are affected the disease rate and cure rate.

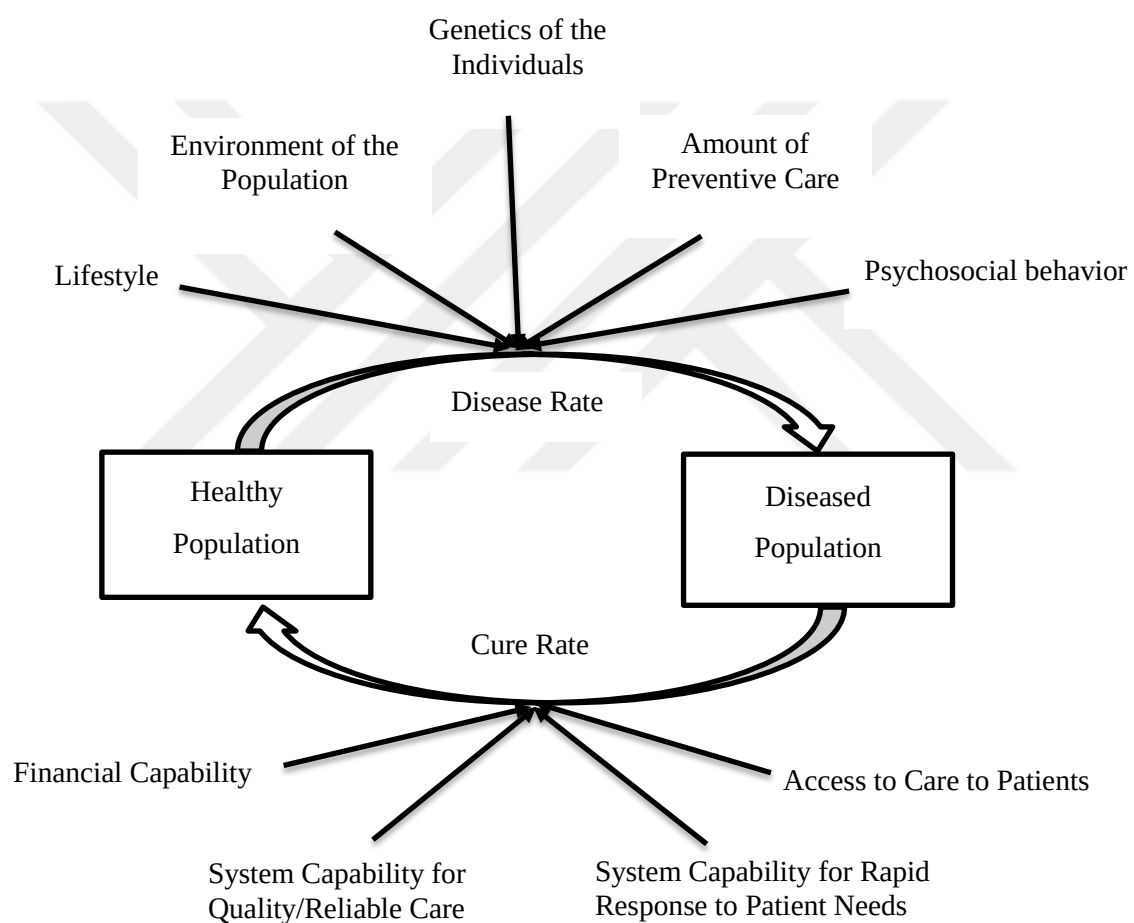


Figure 1.1. Model of a Healthcare System (Wadhwa, 2010)

Today's healthcare environment is continuously changing. It is estimated that global healthcare spend projected to reach \$8.7 trillion by 2020 and spending rates for the world's major regions increases from 2.4 percent to 7.5 percent (Deloitte, 2017). However, in 2019 Deloitte refreshed their estimations about healthcare spending that

spend will be reach \$10.059 trillion by 2022. For that reason, healthcare providers have to respond to patients' growing demands for good and acceptable quality of care.

Continuous quality improvement methods revolutionized perspectives on healthcare quality in the early 1990s and have since been considered a healthcare industry standard. In the study which was conducted by Yasin and Alavi (1999), it is stated that a systematic total quality management (TQM) implementation process can lead to a competitive advantage in the marketplace. On the other hand, there is a common misunderstanding about the concept of TQM studies in health care because these principles are considered helpful just for administrative efficiency and the service quality. However, quality management studies create advantages for medical treatment as well. Therefore, TQM can be applied to make healthcare more efficient, effective and patient oriented (Anderson, 1992; Fried, 1992; Bergman, 1994; Asubonteng et al., 1996; Yasin and Alavi, 1999). Asubonten et al. (1996) focused on TQM initiatives in healthcare industry and stated that it is critical to understand TQM in all dimensions before applying it. Jackson (2001) pointed out that many TQM initiatives fails and the underlying reason is the lack of knowledge, skills and expertise. Difficulties, which are seen during the application of TQM principles in health care industry, are also investigated by several studies (Short and Rahim, 1995; Lin and Glouising, 1995; Zabada et al., 1998). Main focal points about the difficulties in the implementation process can be listed as follows;

- Organizational structure: The main problem is poor communication because of the “functional-hierarchical structure”.
- Leadership style: Organizational structure generally created problems to accept the opinions from subordinates of the leaders. The underlying reason is that most leaders are specialized in their professionalism with authority.
- Organization culture: Highly hierarchical, bureaucratic and authoritarian culture conflicts with the empowerment principle of total quality management.
- Professional autonomy: Sector is highly sectionalized in other terms departments work independently. Because of that, it can be considered as a problem to coordinate a team. Since different departments cannot work as a team, different perceptions and points of view about total quality management can appear.
- Lack of consensus: There is a common misunderstanding about the concept of total

quality management studies in health care because these principles are considered helpful just for administrative efficiency and the service quality. However, quality management studies create advantages about medical treatment as well.

- Internal requirements domination: The main problem is health care industry generally tend to focus on internal requirements rather than patient's requirements.
- Efficiency-oriented: Quantitative performance is critical for the health industry however qualitative performance is also vital and cannot be ignored. Because of the lack of qualitative performance focus affect the understanding of patient's needs and cause poor quality.
- Manpower shortfall: When the professionals in hospital are overloaded, they can only focus on their occupied work. This situation creates problems about the participation of total quality management adaptation processes.

Adaptation of TQM principles into healthcare industry is not as smooth or successful as in the other industries (Yang, 2003). As noted in "To Err is Human (IOM,2000)" healthcare differs from a systematic production process mostly because of huge variability in patients and circumstances, the need to adopt processes quickly with the rapidly changing knowledge base and the importance of highly trained professionals who must use expert judgment in dynamic settings. On the other hand, consequences of failure are so great; the need to reduce or eliminate failures is even more important so understanding the core reasons of the errors in health systems is vital.

It is important to capture information on patient needs, expectations and perceptions to achieve high quality levels. Patient satisfaction enhances hospital image, which in turn translates into increased service use and market share (Andaleeb, 1988). In a study that is published in 2007 by Moumtzoglou, future stated of healthcare and quality is examined. Healthcare satisfaction can be considered both a service quality indicator and a quality component. Zineldin et al. (2011) expressed the importance of patient focused view in healthcare as follows;

"...competitiveness among healthcare organizations depends on patient satisfaction which is created by responding to patient views and needs, healthcare service improvement and overall doctor-patient relationship."

In healthcare, there are many dimensions in terms of patient satisfaction, which should

be analyzed for what is valued by patients, how they perceived service quality and how it can be improved. In 2009, Naidu stated that measuring healthcare quality can help healthcare managers to effectively set control mechanisms and implement improvement programs. There are several theories that attempt to explain how customers evaluate the quality of service in health. What is more, quality studies can vary in several ways since quality perspectives can change among, patients, doctors, insurers, hospitals, business owners and government. In 2000, Ovretveit defined TQM in healthcare and considered examples and results in European Healthcare. Paper reviewed the studies in healthcare sector in Europe compares results between other industries. According to these considerations, future TQM programs are evaluated. Therefore, not only clinical issues should be investigated in detail but also management and relationships issues should be considered in terms of quality management.

At the end of 20th century, many reports revealed strong evidence of widespread quality deficiencies and highlighted a need for substantial change to ensure high quality care for all patients. These major reports are listed as follows.

- “The Urgent Need to Improve Healthcare Quality” published by IOM. In this report quality defect are categorized into three headings such as misuse, overuse and underuse. The first group of quality problems includes avoidable complications that prevent patients from receiving full potential benefit of a service. Second group of problems, overuse, includes potential harm from the provision of a service exceed the possible benefit. Finally, the last group of quality problems consist failure to provide a service that would have produced a favorable outcome for the patient (Chassin and Galvin, 1998).
- “To Err is Human: Building a Safer Health System” published by IOM. This report focused on the negative in an unprecedented way. For the first time patient safety issues such as ensuring safe care and preventing mistakes became a unifying cause for policymakers, regulators, providers and consumers. It is stated in the report that estimates of the incidence of medication errors go undocumented and unreported. Error is defined as the failure of a planned action to be completed as intended (error of execution) or the use of a wrong plan to achieve an aim (error of planning). Report claimed that most people view medical mistakes as an individual provider issue rather than a failure in the process of delivering care in a complex delivery

system (IOM, 2000).

- “Crossing the Quality Chasm. A New Health System for 21st Century” published by IOM. Report pointed out that there should be basic 6 dimensions in every health system. As a first dimension, care should be safe for patients in healthcare facilities as in their homes. Secondly healthcare should be effective. The science and evidence behind healthcare should be applied and serve as standards in the delivery of care. Then efficient healthcare is needed. Care and service should be cost-effective and waste should be removed from the system. Fourth dimension is being timely. Patients should experience no waits or delays when receiving care and service. The system of care should revolve around the patient in other terms care providers should respect patient preferences and put the patient in control. Finally, the last dimension is being equitable. Unequal treatment should be a fact of the past, disparities in care should be eradicated (IOM, 2001).

In 2005, Glickman et al., explained that the need for quality improvement is almost universal on the other hand achieving effective improvements is not well understanding. As effective organizational capabilities they pointed out leadership, human capital, information management systems etc. are essential structural elements of quality improvement. Lagrosen et al. (2007) examined and discussed the effects of quality management in the healthcare sector via studying on three case studies. According to study three factors leadership commitment, participation and continuous improvement have the vital role in implementation of quality studies. In 2008, Duggirala et al. examined the critical dimensions of TQM studies in healthcare and stated that there are 14 critical factors. These are (i) top management commitment and leadership, (ii) human resource management, (iii) process management, (iv) hospital facilities and infrastructure, (v) patient focus, (vi) employee focus, (vii) measurement of hospital performance, (viii) hospital information system, (ix) errors, safety and risk management, (x) service culture, (xi) continuous improvement, (xii) benchmarking, (xiii) union influence and (xiv) governance and social responsibility.

Problems in the coordination of treatment in different services by clinical staff and poor or unsuccessful treatment is one of the most important topics in hospitals however institutional issues, timing and access are the other important topics, which are directly related to quality management. According to Kilpatrick (2009) the effectiveness of

health organizations is affected by the relationships formed by people, technology, resources and administration in providing healthcare. Barrett et al. (2005) stressed that these factors have a dominant role in attaining organizational goals, allowing the health organization to change quality of its healthcare. In 2016, Ketelhöhn and Sanz reviewed literature on healthcare management and conducted a survey among Latin America hospitals. According to study, one of the largest opportunities to increase effectiveness of healthcare system in the region is to train decision makers in the relevant management disciplines.

Today's healthcare environment is continuously changing. The changes in environment, society and political policies will have significant impacts on management in hospitals and cause further problems (Yang and Tsai, 2002). Healthcare providers have to respond to customers' growing demands for good and acceptable quality of care. In 2011, Elg et al., examined developmental trends in healthcare organization management practice and higher management decisions, the patients' voice and policymaker decisions increasingly influence and shape quality improvement efforts.

As the industry structure changes, the role that patients play in defining what quality means have become a critical competitive consideration. For that reason, hospitals need to understand patients' perception of service quality in order to provide optimal health services. However, hospital management should comply with the health regulations and standards that are defined by the health policy makers and academicians while implementing quality improvements. In the near future, healthcare will be put under pressure to offer a high level of quality, safety and customer service continuously while ensuring improved efficiency.

1.2.2. Patient safety management

Nowadays one of the most important topics for the healthcare quality management is patient safety and rights. Involvement of the healthcare related processes, technologies and different industries, which are directly or indirectly affect the healthcare processes, makes the system much more complicated for this reason risk of medical error and unintended events increases.

In 2000, IOM defined patient safety as "...the prevention of harm to patients" in their report called "To Err is Human". Report can be considered as a milestone in the

healthcare industry since it is motivated individuals and organizations to take a serious look at harm caused by medical care. Over the next decade, after IOM report released, there were many efforts to reduce medical error. A large shift in the number of patient safety publications followed the release of the IOM report and the number of federally funded patient safety research awards increased. According to literature, patient safety become a focal point of many researchers and increased its importance over years, as it is presented in Figure 1.2. The incremental change in the number of researches proves that today, providers of healthcare services they have to become increasingly concerned about the patient safety. In the search, “patient safety” and “quality management” is used as keywords for all types of published papers excluding book reviews and academic thesis during determined time interval (2000-2018).

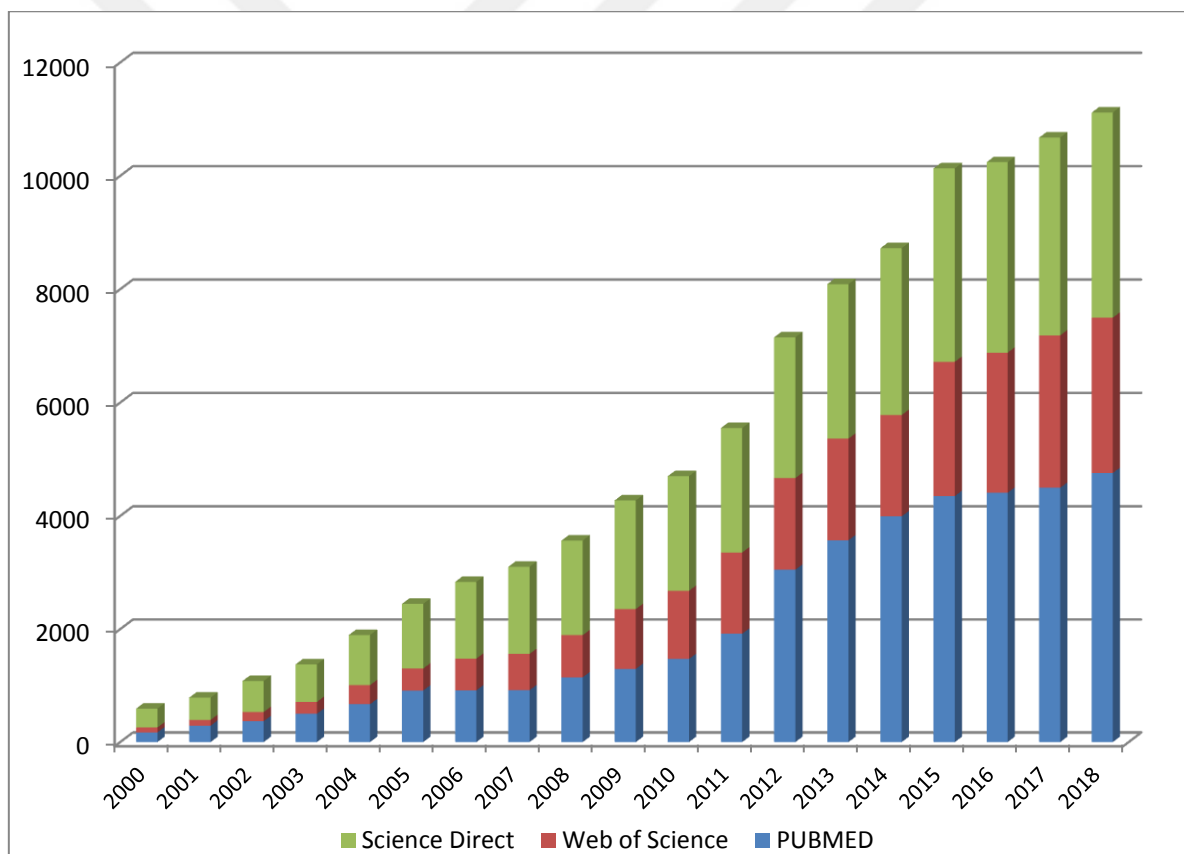


Figure 1.2. Distributions of publications over years with keyword “patient safety”

Nowadays patient safety can be described as the whole prevention actions taken by the medical establishment to avoid the harm that is given during healthcare services. It composes the primary and indispensable requirement of well-qualified healthcare service since warranting the patient safety and preventing the medical errors are found in

priorities of healthcare system at each step of medical care services.

There is an increased focus and some indications of improvement on patient safety issue in the recent years however still 1 in 10 patients develops an adverse event. An adverse event defined as any injury caused by medical care rather than the underlying condition of the patient such as a healthcare acquired infection, pressure ulcer, preventable drug event or a fall in hospitalization. From this point of view, importance of patient safety should also be defined with other related outcomes apart from death rate. In this context, quality, efficiency, attainability and economically are sought in services to meet patients' individual demands. The connection between safety and other dimensions of quality (family centeredness, timeliness, efficiency etc.) is now more appreciated.

Patient safety is gained importance in the early 2000s and still developing its scientific basements. The IOM report stimulated momentum in patient safety and some improvements are achieved such as creation of standard practices and metrics. Increased usage of evidence-based care provides notable improvements; interventions have successfully reduced the rate of adverse events. Barcoding systems are improved to reduce medication administration errors and started used successfully (Poon et al., 2010). 50% percentage of reduction in mortality achieved via training the team about surgery has been shown (Neily et al., 2010). A handoff communication process provides a decrease in 23% percentage of medical errors and 30% percentage of preventable adverse events (Starmer, 2014). Despite the progress after the IOM report, patient safety remains its importance with increased awareness in the past 19 years. Budnitz et al. (2006) stated that every year adverse events caused more than 700,000 outpatients treatment in the emergency departments moreover, 120,000 of these patients require hospitalization. Singh et al. (2014) stated that still more than 12 million patients each year experience a diagnostic error and half of them are estimated to have the potential to cause harm. Globally there are 421 million hospitalization and approximately 42.7 million adverse events each year (Singh et al., 2014) although healthcare measurements became safer since "To Err is Human" report is published (National Patient Safety Foundation, 2015).

Implementation of several quality management methodologies and development of hybrid models not only increased the awareness but also generate an impulse for

multidisciplinary perspectives in healthcare. To better understand the shift in quality management methodologies used in patient safety, literature is reviewed into time intervals. According to analyses, it can be tracked from the Figure 1.3. that, initial studies are focused on the definition and the implementation of the quality improvement however; the focal point has shifted to more specialized issues and hybrid methodologies to understand the dynamics of the system and redesign them.

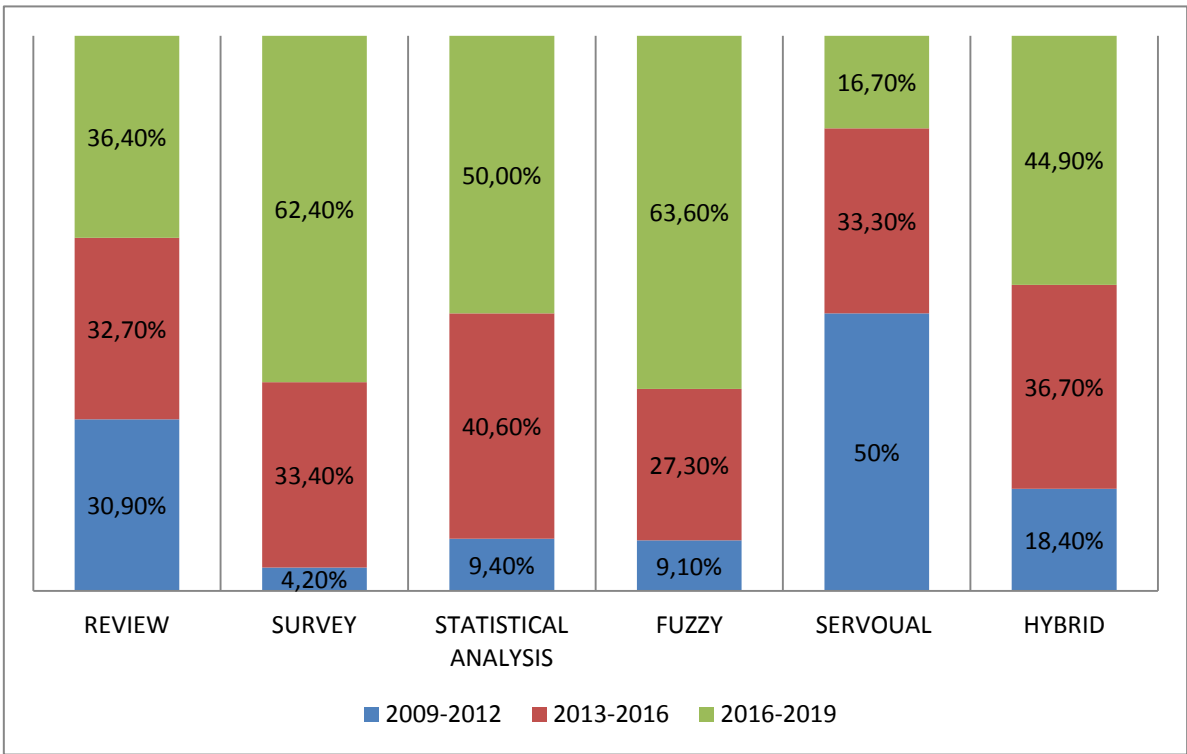


Figure 1.3. Changes in the usage of different methodologies over time

Healthcare institutions need to develop not only a safety climate but also a safety culture to improve reporting, resolution, and feedback. There is a slight difference between climate and culture. A climate generally consist of shared perceptions however culture is institution-wide values and beliefs, which shapes the individuals perception and their act on safety issues. Error reporting systems provide multiple perspectives since these systems include surveys of providers and structured interviews. Analysis of these reports can provide details about latent errors however they cannot be used alone as a reliably measure since several factors may affect them. High reporting rates may indicate an organizational culture for reporting however, it is a well-known fact that there is

generally a limitation using these systems. Leape et al. (2009) concluded their study that progress on patient safety had been insufficient and successful improvements are not permanent if the institution cannot achieve to create a safety culture.

The key attributes of safety culture include acceptance of responsibility of safety by all workers, prioritization of safety above financial and operational goals, encouragement and rewards for identification, communication and resolution of issues, learning from events and provision of appropriate resources, structure and accountability to maintain effective safety systems. A reporting culture encourages and facilitates the reporting of errors and safety issues and commits to fixing what is broken. A learning culture is one that learns from errors, near misses and other identified safety issues. The most important point that should be realized is without a just culture, only minimal reporting achieved; without reporting there is no opportunities to learn and improve. In this point, achieving a safety culture should be a prioritization above financial and operational goals thus administrators plays critical role in encouraging employees in reporting errors by reward systems and in maintaining effective safety systems.

Patient safety gained importance in the early 2000s and still developing its scientific basements. Having a patient safety perception is vital to improve a patient safety culture in the all levels of the healthcare institutions (Güneş et al., 2016; Vifladt et al., 2016; Rigobello et al., 2017; Kallberg et al., 2017, Xie et al., 2017). Therefore, communication, humaneness and patient rights can be considered as the main pillars and patient experiences and perceptions can also be used as a key for improving the system. Increased patient activation can provide successful improvements especially in patient-centered communication, active monitoring, teamwork etc. Although, IOM report stimulated momentum in patient safety and some improvements are achieved such as creation of standard practices and metrics, much of the road is not preceded.

1.2.2.1.Types of medical errors

Medical error is generally defined according to its type of occurrence such as harm, sentinel event, adverse event, near miss, slip, lapse or violations (Albrecht, 2015). There are several studies focusing on the concept of each term and trying to create standardized definitions.

Medical error is an unintended physical injury resulting from or contributed to by medical care that requires additional monitoring, treatment, or hospitalization, or that result in death. These errors are classified (Akalin, 2005) into five sub groups depending on their types such as (i) medication errors, (ii) surgical errors, (iii) diagnostic errors, (iv) systematic errors and other (transfusion, falls, infections etc.) Akalin (2005) categorized common reasons of medical errors into two classes, errors that are related human which consist of fatigue, lack of training, lack of prevention, lack of communication, wrong decision, logical mistakes etc. and errors that are institutional factors such as physical conditions, policies, administrative structure, lack of leadership, inadequate equipment etc. Adams and Garber (2007) also supported the idea to divide common errors into two classes' ad human workforce and system. According to their study, systematic errors are caused more important problems rather than human related errors.

IOM (2000) defined an error as the failure of a planned action to be completed as intended (Error of execution) or the use of a wrong plan to achieve an aim (Error of planning). National Patient Safety Foundation (2003) classified errors into three sub categories such as; errors of commission (doing the wrong thing), errors of omission (not doing the right thing) and errors of execution (doing the right thing incorrectly). In f,gure 1.4. general classification of medical errors are presented.

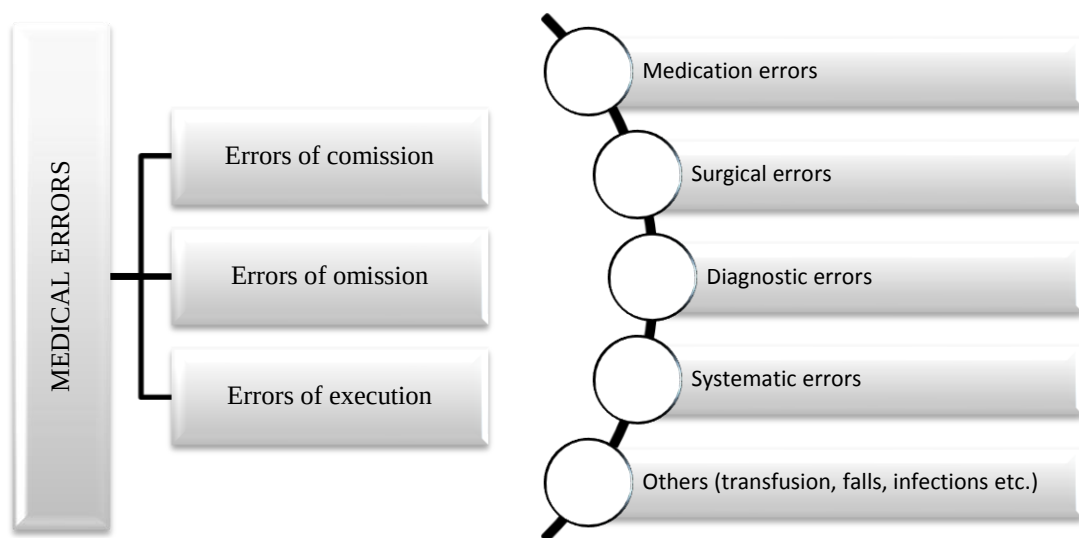


Figure 1.4. General classification of medical errors

In the report called “Free from Harm” which is published by IOM in 2015, error is defined as an act of commission (doing something wrong) or omission (failing to do the

right thing) that leads to an undesirable outcome or significant potential for such an outcome. In Figure 1.5. relationship between different definition types of medical errors is presented.

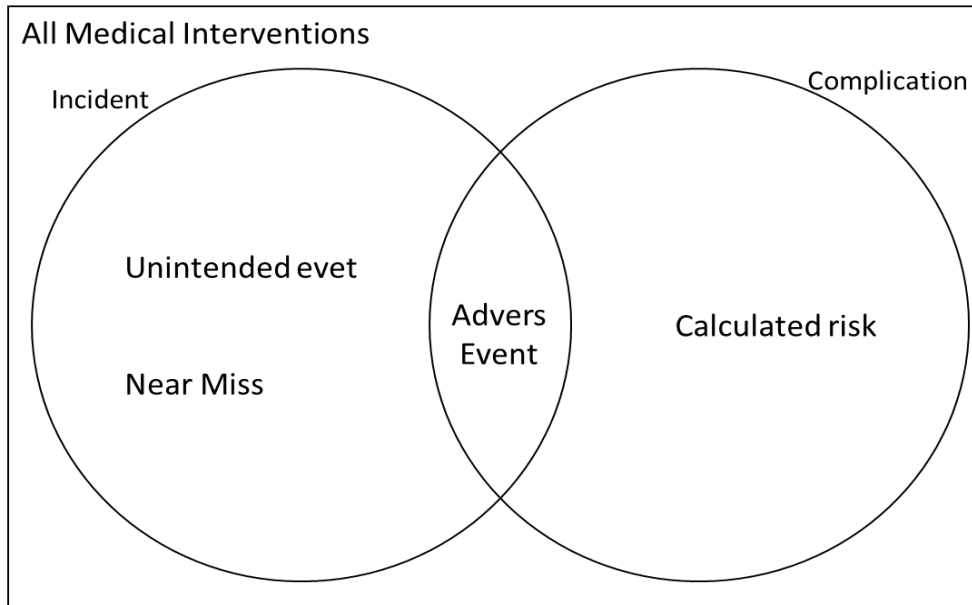


Figure 1.5. Relationships of medical error definitions (Smorenburg et al., 2007)

Rathert et al. (2012) examined the perceptions of the patients and their families about the patient safety and revealed that although patients play a proactive role in reporting adverse events, clinicians define safety differently from patients. Therefore, understanding of how to define safety is a vital issue for healthcare institutions. According to the report “Free From Harm” terms that are used to define patient safety is as follows (National Patient Safety Foundation, 2015);

- Adverse event: An unintended event because of the performance of a healthcare provider and / or healthcare system.
- Complication: An unintended negative outcome which develops as a cause of treatment of an illness already present during or after care and either necessitates treatment or leads to permanent harm
- Calculated risk: A deliberately and consciously taken risk in which the benefits of a treatment / intervention are deemed to offset / countervail the possible burden of serious harm.
- Incident: Unintended events stemming from the health care process which either occurred or could have occur or still can occur to harm patient.

- Near miss: An unintended occurrence with the capacity (potentially) to cause error but does not have adverse consequences because of timely and appropriate identification and correction activities.

In healthcare systems, many factors influence the rate of errors. The possible reasons of errors are usually associated with some combination of the team, the task performed and the patient. However, the less visible factors such as context, management and work environment must also be addressed. There can be several reasons, which can affect and cause problems in patient safety such as missed information, missed coordination, lack of control processes, non-standardized medical equipment etc.

“Swiss Cheese” model which is originally developed by James T. Reason and Dante Orlandella is of the mostly known system that deals with errors. The model is based on barriers, each representing a layer of swiss cheese with many holes (Goldberg, 2019). When layered on top of one another, the holes, which are where errors can happen, eventually become blocked, preventing lapses and mistakes from creeping through. However, when errors occur due to the medical staff (termed an “active failure” in the model) or caused by inherent flaws in protocols or procedures (termed “latent conditions”) in such a way that they all line up through each barrier, then you have an opportunity for a potential disastrous patient outcome. In Figure 1.6. an example for model is presented.

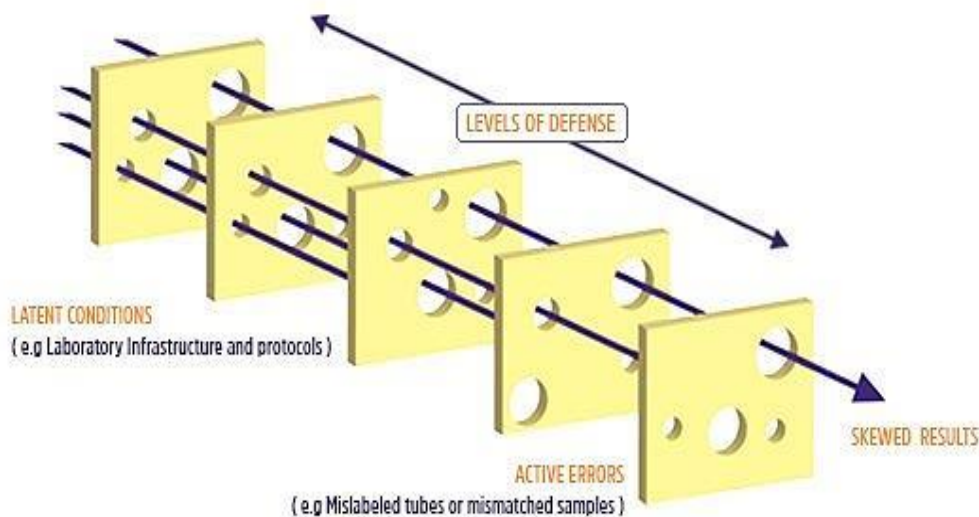


Figure 1.6. Example for “Swiss Cheese” model (Goldberg, 2019)

Current researches revealed that most of the medical errors caused by the system rather than individuals. According to the study conducted by Blendon et al., (2003) 35% of doctors and 42% of the total society are believed that there is a medical error during the treatment process. Shoen (2005) stated that 34% of the total society in USA believed that there is a medical error during the treatment process and USA is in the first place with this percentage in the “Commonwealth Fund International Survey”. King (2007) stated that the core reasons of the patient safety problem are lack of communication (%70), lack of training (%60), lack of patient evaluation (%40) and lack of labor (%25). For that reason, emphasis should be placed on the system of care, not only to prevent errors but also to learn from error and built on a culture of safety that involves healthcare professionals, organizations and patients.

From healthcare industry point of view, there is an urgent need to investigate and identify the critical components to achieve effective healthcare services. It is a well-known fact that competitiveness among healthcare organizations highly depends on patient. Their perceptions can shape with responding to patient views and needs, continuous healthcare service improvement and overall doctor patient relationship. Since patient safety can be affected from all domains of healthcare, which can be classified as clinical, management and relationship domains, whole system should be investigated in terms of quality management. Carayon et al. (2006) stated that most errors and inefficiencies in patient care arise not from the solitary actions of individuals but from conflicting, incomplete or suboptimal systems of which they are a part and with which they interact. Many tactics are available to make system changes to reduce errors and adverse events. Commonly they aimed to reduce complexity, optimize information processing, automate the processes, consider limitations and constraints and mitigate the unwanted side effects of change (Nolan, 2000).

1.2.2.2. Medical error determination

Medical errors affect the patients, the nurses, and the healthcare establishments negatively. Therefore, all members of healthcare service should be attentive about the medical errors. In this context, warranting the patient safety and preventing the medical faults appear to be one of the basic elements of quality in healthcare service. Determination of the medical errors at the right time and revealing the core reasons is a

vital part of the solution. In order to give well-qualified healthcare service, medical establishments should meet basic requirements, should apply the process of patient safety perfectly in a flawless way, and should perform the processes with appropriate procedure.

IOM (2000) has noted that designing healthcare processes for safety involves three-step strategy; (i) designing systems to prevent errors from occurring, (ii) designing procedures to make visible the errors that occur, and (iii) designing procedures to mitigate the harm to patients from errors that are not intercepted or are not detected. To prevent errors, all the related factors should be determined in the first stage and must be considered in detail. Joyce et al. (2005) developed taxonomy in their study to reveal the approaches to medical error in terms of patient safety. According to their study, there are three different points of views, the empiricists, the organizational rationalists and the professional culture promoters, however understanding an error and the core problem of the error requires multi-disciplinary collaborations (Joyce et al., 2005).

It is almost impossible to reduce the rate of errors to zero, the aim of the system should be reduce to zero the instances in which an error harms a patient. For that reason, a safe system should make errors visible so that they can be corrected before causing harm. Not all errors will be intercepted before reaching the patient. When error undetected, processes are needed to be so quickly reverse or halt the harm caused to patient by the error.

Reporting mechanisms are the common type of methodology that is also commonly used to identify errors, take precautions and analyze them (Dienemann, 1998; Skurka, 1998). Although reporting errors can be considered as the initial step in quality improvement process, these mechanisms mostly became unsuccessful. The underlying reason is that creating reliable reporting environment is a challenging issue and cannot be guaranteed in the most health institution (Skurka, 1998).

Thomas and Peterson (2003) identified eight methods used to measure errors and adverse events in healthcare and these are (i) morbidity and mortality conferences and autopsy, (ii) malpractice claims analysis, (iii) error reporting systems, (iv) administrative data analysis, (v) chart review, (vi), electronic medical record, (vii) observation of patient cure and (viii) clinical surveillance. Each of these measurement

systems can provide important and actionable information about healthcare systems; they also have different limitations and disadvantages. Thomas and Peterson (2003) suggested that a comprehensive monitoring system for patient safety might include combinations of the measurement methods.

Morbidity and mortality conferences aim to learn from surgical errors and adverse events. Method is familiar to healthcare providers however generally focused on diagnostic errors. Analysis of medical malpractice claim files is another method used to identify errors. Relative to other methods, the strength of claims file analysis lies in its ability to detect latent errors. However, claims are a series of highly selected cases from which it is difficult to generalize and cannot be used to estimate the effect of an intervention to decrease errors.

Error reporting systems provide multiple perspectives since these systems include surveys of providers and structured interviews. Analysis of these reports can provide details about latent errors however alone cannot reliably measure incidence and prevalence rates of errors since several factors may affect them. High reporting rates may indicate an organizational culture for reporting however, it is a well-known fact that there is generally a limitation using these systems. On the other hand, administrative data analyses utilize readily available data and theoretically provide an attractive source of data for measuring errors. Although the analysis commonly used, the limitation here is that data may be incomplete and subject to bias. The other method, which is also commonly used, is chart review. Large, population-based reviews are useful to monitor patient safety in contrary there is problem because of reliability and incomplete documentation. Electronic medical record method is also monitors real data. This method integrated multiple data resources and can be considered as inexpensive after initial investment, which is expensive to implement. Observation of patient care method detects more active errors than other methods but practical and methodologic issues limit direct observations. On the other hand, it is possible to be overwhelmed with information. The last method, clinical surveillance, considered potentially the most accurate and precise method but tends to focus on specific events in a focused time and place so the most important disadvantage of this method is being expensive and have problems in detecting latent errors.

Pronovost et al. (2006) developed a framework for measuring patient safety in two categories. The first is valid rate-based measures which is used to answer how often do health institutions harm patients. The second category includes indicators that are essential to patient safety but cannot be measured as valid rates. In general, two different approaches are used for the improvement of patient safety systems, proactive and reactive approaches. Proactive approach supports the idea that it is not necessary to wait of the occurrence of an error or harm. The main point is to take precautions for the errors which have a possibility to occur and caused harm in the near future for that reason focal point is the processes which have high risks. Analysis depends on the experiences and knowledge that is already happened in the institution and processes that are defined as risky in the literature. Reactive approach is implemented after an error or a harm is occurred. Improvements are defined via analyzing the issues with cause and effect analysis in which core reasons determined related processes and systems analyzed, new design or improvement points identified to reduce risk and reappearance prevented.

Hincapie et al. (2016) stated that patients might be the most reliable reporters of some aspects of the health care process; their perspectives should be considered when pursuing changes to improve patient safety. Since the focus point is patients for the hospitals, achieving high quality levels in the related area gains importance in terms of hospital's reliability.

Care systems changes in several ways but most importantly, the role of patients and the way of their perceptions is changing. For that reason, hospitals need to understand patients' expectations and their concerns of service quality due to provide optimal health services. Recently, application of lean management to hospitals is a popular research area however hybrid methodologies are more effective to improve overall system.

Healthcare organizations experience challenges of complexity, co-production and service intangibility. Considering patient safety as a priority, redesigning the system requires using hybrid methodologies. In practice, it is not clear in most cases that the underlying cause of an undesirable outbreak is the nature of the medical illness, or an error, or the result of an unsuccessful medical process. Moreover, it is also possible that these two different situations occur at the same moment. The greatest challenge in the healthcare process is the need to have very different quality data and to handle many different

dimensions at the same time. The process is human-oriented and variation in the data makes the system's structure very complex.

1.2.2.3. International perspectives and Turkey

Today, importance of quality in healthcare sector is known for all levels of the industry and awareness of patient safety issues increases in worldwide. In the report called “Free from Harm (2015)”, it is stated that based on the healthcare measurements they conducted healthcare became safer since “To Err is Human” report is published. Administrators plays critical role in encouraging employees in reporting errors and in maintaining effective safety systems. It is a well-known fact that in this point the other critical dimension of the system is governments which should make policies and regulations with the aim of creating standardized patient safety systems. In Table 1, patient safety systems of several countries’ are summarized.

Table 1.1. Global efforts on patient safety

Country	Reporting System		Patient Safety System
	Mandatory	Voluntary	
United Kingdom	√	√	National reporting and learning systems is founded to learn from side effects and develop a reporting culture. %90 of the health institutions in England are registered the system.
USA	√	√	There is not a national reporting system on the other hand 21 states out of 50 have a compulsory reporting system. Unexpected deaths and wrong side surgery are one of the main events that must be reported.
Australia	√		The Australian Commission for Safety and Quality in Health Care was established in 2006 to lead and coordinate national improvements in the safety and quality of health care. The primary aims of the National Safety and Quality Health Service (NSQHS) Standards are to protect the public from harm and to improve the quality of health service provision.
Czech Republic		√	Error categories: hospital related infection issues, side effects of medications, transfusion reactions and medical equipment errors.
Denmark	√	√	Healthcare professionals have to report side effects while design of the system protects the private information and rights of the health professionals. Moreover, system allows everyone to report an error who witnessed the event.

Table 1.1. (continued)

Norway	√		Hospitals and other specialist healthcare services carry incident reporting system which is established and maintained by hospitals. System enables employees to report.
Italy	√		System is mandatory and is focused on very serious incidents which are chosen from the appropriate category from determined lists by health professionals.
Netherlands		√	Serious incidents have to be reported to the Health Care Inspectorate by professionals however remaining incident reporting is voluntary. However it is a must to report an event which ends with a death. Patients and employees can also report the related issue.
Germany		√	Nationwide reporting system which is an internet-based system and open to everyone who wants to report a near miss and receive an analysis about it. There are several reporting systems in nationwide; it can be investigated in another study.
France	√	√	There is a national reporting system which is launched in 2006 coordinated by National Authority for Health. System operated by each of the professional 'at risk speciality' organizations.
Slovenia	√	√	Errors called as sentinel events, which are defined as unexpected events such as major function loss, transfusion errors, wrong side surgery etc., are reported to Ministry of Health by hospitals.
Sweden	√	√	Existing quality systems are rearranged and standardized by National Board of Health and Welfare. Side effects, equipment errors and other events that create harm should be reported. Patients can report to a regional Patients Advisory Committee as well.
Turkey	√	√	In 2015, last version of the quality standards of health systems is published by Ministry of Health. Safety reporting system is a platform that health institutions and professionals can report medical errors thus they can inform with common errors and precautions of these errors.

In Turkey, generally patient complaints and rights are put forward safety by government. In 2003, initial studies of patient safety are started, hospital standards are improved and pilot studies are carried out with trainings. %69 of healthcare employees and %10 of the society are declared themselves or one of their relatives is face to face with medical errors (Çakmakçı, 2011).

In 2015, last version of the quality standards of health systems is published by Ministry of Health. The main aim of the report is trying to provide the optimal quality level for that reason in all hospitals goals are defined to achieve standards as an initial step. Therefore, international health organizations, related developments, necessities and priorities of Turkey are considered.

Report includes the basic information about the quality process in healthcare thus can be considered as guidebook for hospitals and other stakeholders for the improvement of healthcare quality. Report is formed of 5 dimensions (Institutional services, Patient and Employee focused services, Medical services, Support services, and Management of indicators), 39 parts, 557 standards and 1100 indicators. Table 1.2. presents the dimensions and parts of the indicator system.

In a report called “Standards of Accreditation in Health”, which is also published by Ministry of Health in Turkey in 2015, patient safety is considered as one of the main dimensions of the quality goals of hospitals. Report emphasized that services provided by hospitals can only be considered as quality service if the related hospital achieved the determined quality goals. Generally, goals of hospitals are examined in two main categories. First category consists of organizational goals such as efficiency, effectiveness and productivity. Goals that are in the second category are directly related the patients such as patient safety, patient centeredness, sustainability etc.

Table 1.2. Indicator system of quality standards of health report (Adapted from Quality Standards of Health Report Turkey, 2015)

Institutional Services	Patient and Employee focused Services	Medical Services	Support Services	Management of Indicators
Organizational structure	Patient experience	Patient care	Facility management	Tracking indicators
Quality management	Access to service	Medication management	Hospitality management	Department based indicators
Documentation	End of life services	Prevention of infections	Information management system	Clinical indicators
Risk management	Healthy work life	Sterilization services	Waste management	
Safety reporting system		Transfusion services	Outsourcing	
Emergency and disaster management		Newborn intensive care unit	Material and equipment management	
Training		Emergency services	Medical records and archives	
Social responsibility		Operating room		
		Intensive care unit		
		Radiation safety		
		Childbirth service unit		
		Dialyzer unit		
		Psychiatry services		
		Biochemistry Lab.		
		Microbiology Lab.		
		Pathology Lab.		
		Tissue typing Lab.		

In Turkey, medical errors are already defined in a system called “safety reporting system” which is a kind of web based platform that health institutions and professionals can report medical errors and also they can be informed with common errors and precautions of these errors. In safety reporting system, medical errors are classified into four main categories such as laboratory, medication, general/ surgical and patient centered errors as presented in Table 1.3.

Table 1.3. Medical error categories

Laboratory Errors	Medication Errors	General /Surgical Errors	Patient Related Errors
Pre-Analytic	Storage	Clinical surgical procedure preparation	Physical Structure Related
Analytic	Demand	Transfer to the operating room and patient acceptance	Device/Equipment/System Related
Post-Analytic	Preparation	Operating room surgical procedure	Medical Record and Clinic Evaluation Related
	Transfer	Pre-anesthesia preparation and control	Communication Error
	Implementation	Controls before surgery	Care, Diagnosis and Treatment Process Related
	Post-implementation	Follow up and control during operation	Patient/ Attendant Related
		Controls at the end of the operation	Errors Concerning the Transfusion of Blood and Blood Products
		Departure of the patient from the operation room and transfer	



2. METHODOLOGY

In daily life, people prefer to use natural language instead of numbers, although it is less certain. The underlying reason is that people can more easily interpret and evaluate information in the form of linguistic expressions rather than exact, deterministic expressions. Additionally, uncertainty, lack of certain thought and vagueness in decision-making makes it more complex.

Lin et al. (2017) stated in their study that decision makers are required to provide their opinions about a criteria or an alternative with a crisp data in the initial stages of decision-making problems. On the other hand, precise numbers are not a good way of presenting the uncertainty of human thinking thus evaluations is not presenting the complexity and the uncertainty of the real life. Therefore, fuzzy logic and its extended forms are vital especially in decision-making problems.

From healthcare systems point of view, the situation becomes more vital for making correct analysis. Healthcare systems are not deterministic in terms of their structures. Analyzing the system is quite difficult since the healthcare system itself and each of the factors affecting the system is probabilistic and uncertain. It is almost impossible in many cases to make definitive definitions of real-life applications in the health field or completely explain the relationship between medical concepts. The imperfect knowledge situation is inevitable and this structure of medical data is causing uncertainty in the decision-making process.

Development of a comprehensive patient safety system is a complex problem and requires hybrid decision-making models. For that reason methodology are divided into 3 sub- parts based on the steps of the proposed model. The rest of the methodology part is structured as follows.

The initial stage of the proposed model in this study highly depends on the safety assessment calculations. For that reason, in the first part of the methodology, safety assessment literature is investigated for attribute selection then background of the main formulation of the proposed model is presented. In the study, it is considered to use fuzzy sets in terms of the structure of the health data. The expression of membership functions by a single value both makes the situation more difficult for the decision maker

and narrows the scope of the analyses. The main reason not only the complexity of the data but also the need of that the decision maker's level of hesitation should be added to analyses. For this reason, in the second part of the methodology, fuzzy logic and its extended versions finally probabilistic linguistic terms sets are presented. Finally, in the third part, similarity and distance measurements that are used to calculate overall index value are presented. In solving decision making problems similarity and distance measurements are vital to find the difference among elements.

2.1. Safety Systems Assessments

Several measurement and assessment tools are generated for safety management systems in literature however there is still no single definition. USA Department of Labor defined a safety management system, as "...A safety management system is an established arrangement of components that work together to attain a certain objective." In general, safety assessment models are classified into two sub groups as qualitative and quantitative methods. Qualitative methods generally define the risks with terms like high, moderate or low whereas quantitative models translate risk categories to numbers. In literature, decision matrices are also used to analyze the relationship between two or more variables. These methodologies are generally called risk assessment matrices which are firstly developed as a USA military standard to meet the safety program requirements. The widely known type of risk assessment matrix is called L-type matrix in which risk degree is calculated with the multiplication of probability and severity of the related risk.

In 2001, Hudson stated that safety management systems are systematic applications of management processes for the hazardous problems that companies faces. Therefore, a safety management system can be considered as a system in which risks are managed through identifying to controlling them. From this point of view, definition of quality management initiatives and safety system assessments are similar therefore, safety management systems in healthcare institutions can be considered as a component of a quality management system (Harten et al., 2007).

One of the most important issues of quality management systems in healthcare institutions is patient safety in which the process starts with the identification of risks and

ends with managing them to prevent harms. In general, patient safety related problems are tried to solve by focusing on a single incident at a time but often the core reasons are not revealed so the same error can be occurred again. Furthermore, in most of the cases, core problems for patient safety are not related with the prevention or improvement mechanisms. Harten et al. (2007) stated that there should be risk analysis, preventive measures, evaluation processes to prevent risks and controlling mechanisms in safety management systems. In their study, minimum requirements of safety management system is described such as (i) pro-active periodic risk inventory, (ii) incident and complication reporting, (iii) systematic and structured approach for improvements and (iv) strategic and operational activities.

In 2007, patient safety toolbox is published which is one of the comprehensive studies of SIMPATIE (Safety Improvements for Patients in Europe) project. The project has been designed to establish systematic knowledge repository on patient safety and define recommendations for health services for improvements. In the report, several methodologies are presented as patient safety tools, which are briefly explained in the Table 2.1. as follows.

Table 2.1. Safety assessment tools

Methodology	Description	Advantages	Disadvantages
Move your Dot	In 2003, Institute of Healthcare Improvement (IHI) generated this model for safety management in hospitals in which mortality rates are measured, evaluated and aimed to reduce. In the method, mortality rates, which are standardized based on several variables, are used to improve care via comparing the hospitals with each other and the national average. After a standardized mortality rates are calculated, mortality rates in the determined hospital level can be measured and improvements are planned to reduce it.	Miscommunication, scheduling errors, adverse events and non-response to a question are evaluated. Tracking errors in the system, learning from them and improving the care processes are main advantages. In this analysis, inter-hospital variation can be tracked as well	Filling the records is not a controlled process and requires improvements. Many problems can be encountered during the data collection phase.
Trigger tool	This tool is generally used to screen the current state and identify adverse events. Further analysis for the adverse events provides a starting point for improvements.	It is suitable to monitor number of adverse events in a hospital, at the department level or a specific care level.	Screening and assessment take time since assessment should ideally made by two individuals independently and agreement can be low.
Bow-tie model	A systematic model is generated in which risks, preventive and recovery barriers of processes are detailed as a whole picture. In the model risk factors, preventive and recovery barriers are integrated. The route of an incident can be tracked from beginning to the consequences via	Model is very useful to analyze the current safety management model and the determination of root causes.	Creating a complete model for each risk takes too much time and number of sessions in which multidisciplinary focus is needed. Moreover, the success of the analysis highly depends on the

	presenting the failures in preventive and recovery barriers.		motivation of the participants. Thus, it is also too easy to set wrong priorities.
Health Failure Mode and Effect Analysis - (H)FMEA	FMEA is a simple and widely used methodology which basically prioritizes risks based on a calculated risk number. The main reason of method's extensive use is the simple structure of the method which is basically focuses on preventing deficiencies and improving safety.	Model makes the risks more visible so it is possible to take precautions before incident takes place.	(H)FMEA takes too much time since minimum four participants is needed. For that reason model is time-intensive. Time, resources and space must be made available to implement the method properly.
Root Cause Analysis (RCA)	Method generally used to evaluate the incident with two basic questions; “what happened?” and “why did it happen?”. The main aim is preventing the occurrence of similar accidents in future via learning from the experiences.	Method provides and objective description of the error and the root causes of it. RCA not only help to create recommendations to prevent occurrence of similar errors but also creates insight in employee.	RCA is a time consuming approach as well and moreover not every employee is suitable to carry out the analysis. Moreover, contributes of RCA to improve patient safety has not been scientifically presented.
PRISMA	The model is focuses on the processes rather than persons. Casual tree, which is a visual presentation of the related error and all the information about it, is used as a starting point to classify basic causes. Then, findings are translated to preventive measures.	Model provides detailed analysis in terms of investigated error via quantitative and qualitative insights. Model also makes conclusions more visible since an entire collection of incident are examined.	In the model, after casual tree and the classifications of the basic causes are made, a link with context variables for each basic cause should be created. If PRISMA is planned to use to compare data between organizations, it is vital to design variables uniformly.

In addition to these mentioned mostly used models, there are several models that can be used within hybrid methodologies for safety management. Some of these methodologies are briefly explained as follows.

- Benchmarking can be used to measure and compare quality and safety of care. After indicators are determined, the healthcare institution can make assessment for their processes and take actions. However, the main problem in benchmarking is comparisons of different populations. Storms (2007) stated that in these cases external accountability is dangerous.
- Bundles, which is defined as a set of precautions, used collectively. Smorenburg (2007) stated that caregivers are generally trend use simple bundles of care processes to make changes. Application of the bundle will be successful and effective method in reaching a set of objective. However, limited number of interventions can be used to create bundles.
- Rapid response teams are used to improve communication between several care providers as supporting function. Studies show that rapid response teams can be called if a nurse or doctor suspects that a patient is at risk. However the critical issue is original care providers must continue to fell involved (Salm, 2007).
- The time-out procedure is a simple check with a standardized questionnaire to ensure the right operation is being performed. The Joint Commission in the USA included time-out procedure in operating rooms as an accreditation criteria. Ross (2007) time-out procedure should be used to ensure that all checkpoints are summarized and checked with the entire team before surgery.

Management of safety system in healthcare institutions is a complex problem and requires hybrid models in which comprehensive analysis are made. In the examined safety management methodologies, it is seen that in each methodology there are some drawbacks. This situation is emphasizing the need for a hybrid model in order to ensure patient safety. Focusing the incidents one by one is not only a time consuming system but also highly depends on the human oriented mechanisms. Moreover, the underlying reason of the need for a standard patient safety system is providing the reliability of the measurement system before determining regulatory and preventive actions to ensure patient safety.

In this study, focal point is prioritizing the errors to create improvement mechanisms for safety management. For that reason, initial step of each methodology is investigated and FMEA is chosen as a proper method since a risk priority number for each error is calculated. FMEA has been proven to be one of the most important early preventative initiatives for companies and its popularity still increases. Another reason that FMEA is selected among other methodologies based on its structure in which three dimension namely probability, severity and detectability is used for calculating of the risk magnitude.

FMEA was designed in 1960 by NASA afterwards, Ford Motor adopted and promoted it in 1977 (Maheswaran and Loganathan, 2013). Today, it is used as a risk assessment tool in various fields such as aerospace, automobile, chemical, electrical industries and military etc. (Su and Chou, 2008).

Failures in any system might be varied and have different impacts. For that reason, each failure mode with high risk should be taken into account for evaluation. At that point FMEA, as one of the main systematic techniques relative to failure analysis (Aslani et al., 2014), are considered one of the most reliable method (Su and Chau, 2008). The underlying reason is its success in detecting the potential failures in the system (Özveri and Kabak, 2016). Therefore, method enables to decrease the potential risks and to improve the quality, safety and reliability of a system by engineers (Su and Chou, 2008). Moreover, a significant point of FMEA is that it is a proactive approach (Özveri and Kabak, 2016) thus it is possible to prevent them before they happen.

Risks are prioritized with regard to their Risk Priority Number (RPN) in FMEA (Palaniappan, 2014). In order to obtain RPN for each failure mode, the value of the three risk criteria has to be known. These risk criteria are severity (S) which indicates the effect of failure, occurrence (O) which is the frequency of failure, and detection (D) which is the probability of detecting the failure (Özveri and Kabak, 2016). After the identification of values of the risk criteria, RPN can be calculated as follows (Maheswaran and Loganathan, 2013);

$$RPN = S * O * D \quad (2.1)$$

In traditional approach, the values of S, O and D and their weights (if exists) for each

failure mode are given by experts, according to their importance level rating scale between 1 and 10 (Maheswaran and Loganathan, 2013). Then, determined levels and weights are simply multiplied to obtain the overall RPN. Finally, RPN scores are listed in the descending order and prioritizing list is achieved. However, in real life cases this simple structure which is one of the strongest sides of the model turns to one of the main reason of the shortcoming that the model has.

Chang et al. (2014) stated in their study that there are significant criticisms about traditional use of FMEA such as duplication in RPN elements, violation of the measurement scale assumptions, problems in considering the weights of each dimension and drawback of determining the subjective structure with current RPN scale. Wu et al. (2014) tried to improve the calculation of RPN and stated that each of the three dimensions have different characteristics so their calculation should be different.

In 2017, Liu et al. also stated these shortcomings of traditional RPN calculation and pointed out the problems in setting the weight of risk factors. Huang et al. (2017) summarized the major flaws as using crisp numbers in evaluation of risks, sensitive formulation of RPN to the variation and weighting of each dimension. They searched the literature and proposed a new form of FMEA which uses linguistic distribution assessments on the failure modes.

In the literature, there are several studies including the shortcomings of RPN calculations. It is easy to better understand the limitation of traditional calculation of FMEA with a simple example. Assume that, for a specified risk type, Occurrence (O) is equal to 2, Severity (S) is equal to 5 and Detection (D) is equal to 7 in the first failure mode and “O” is equal to 7, “S” is equal to 5 and “D” is equal to 2 in the second failure mode. In that case, RPN values for both failure modes are the same as equal to 70, although the each score have different effects on the failure risks. Even if each criterion has different weights, according to the multiplication rule the total score will be same for both of the failures. This deficiency causes the problem of assuming the severity, occurrence and detection’s importance as the same (Özveri and Kabak, 2016). However, in real-world cases, the relative importance of each criterion should be taken into account. As it is clearly seen by the given example, these limitations of traditional calculation of RPN values make risk assessments deficient.

In literature weighted product (WP), which is one of the scoring methods used in case there are multiple criteria having different importance weights, is used to overcome the mentioned problems. Within the method, the importance weight of each attribute (w_j) becomes exponents and the score of an alternative (V_i) is calculated (Yoon and Hwang, 1995).

$$V_i = \prod_j (X_{ij})^{w_j} \quad (2.2)$$

where i and j represents the alternatives and attributes respectively. In the equation, X_{ij} refers to score of alternatives with respect to attributes, w_j refers to importance weights and finally V_i represents the total score of the alternative. WP model provides to obtain a consistent result by using the specified importance weight for the interested factor (Zavadskas et al., 2012). Therefore, the new RPN is calculated via WP to eliminate the deficiency of the traditional approach of FMEA with the formula;

$$RPN = S^{W_S} * O^{W_O} * D^{W_D} \quad (2.3)$$

Karasan et al. (2018) used the weighted formula in their risk assessment methodology and created a model for safety and critical effect analysis. Although the model based on the basics of the FMEA, new form of the weighted RPN calculations provides better results.

2.2. Fuzzy Sets

The fuzzy set theory was first put forward by the Azerbaijani-born Lotfi Zadeh in 1965 (Zadeh 1965). Theory can be seen as a generalized version of the traditional set theory and makes important contribution to the representation of uncertain data since it is more compatible to real life cases. In this way, instead of classical set theory, which uses precise definitions, fuzzy effects can be used in methodologies. After the development of fuzzy logic theory by Zadeh in 1965, many applications in different directions have been made and used frequently in the literature. Fuzzy logic can be defined as a system aiming at creating an infrastructure for reasoning on ambiguous propositions by focusing on verbal variables in natural speech language. This system reflects the accuracy and uncertainty in natural speech language (Bojadziev ve Bojadziev 2007: 44). It is used in the logical model process to help people make rational decisions in environments

affected by uncertainty (Liu, 2009).

In the classical set theory, an element whether or not it belongs to a set A , which is the subset of the universal set E of elements, is strictly bounded. The membership of an element to a set A is represented by the 0-1 membership function. If an element is a member of a set A , the membership function is equal to 1. However, it is not exactly the right approach to analyze events with two valued 0-1 logic because of the uncertainty in real life. For this reason, Zadeh (1965) has proposed the definition of fuzzy sets expressed by graduated membership functions instead of classical sets where set elements are represented by the binary membership function. The main reason is the fact that the concept of classical sets is inadequate in the real world, especially when dealing with complex systems involving people. In this way, Zadeh suggests using clusters expressing membership functions using infinite value between $[0,1]$.

A membership function for a fuzzy set A which is defined as a subset of universal set E is represented by $\mu_A(x): E \rightarrow [0,1]$. In this equation $\mu_A(x)$ represents the membership degree to set A . Thus, fuzzy set A is shown as $A = \{\mu_A(x), x\}$.

In a membership function, value of 1 represent that the related element is completely a member of the set. The values that are close to 1 shows the membership is strong but partial, membership values greater than 0 and less than 0.5 indicate that the element is close to being member of the set but is still weak. Finally 0 membership value indicates that the element is not a member. In other terms, the membership interval is an indication of the trustworthiness of an element in a fuzzy set.

It is difficult to model systems that are affected by people's decisions, feelings and perceptions with numerical values. For this reason, it is necessary to use linguistic variables and linguistic labels which are very close to the human thought system rather than exact values in the thinking and decision making processes which are very complicated. Linguistic variables are words that substitute exact numbers, variables that are natural or artificial expressions. It is possible to include less certainty by using words or phrases instead of exact numbers. In a simple way, fuzzy logic turns the binary sharp logic like "cold-hot, fast-slow, open-close" into loose qualifiers like "cool-warm, a bit fast - a bit slow; little open-little close".

Over time, the scope of the theory has been expanded and used in the analysis of

processes that have different data systems. In basic fuzzy sets which are also called as “Type-I Fuzzy Sets”, the membership function value equals a certain value in the range $[0,1]$. On the other hand, this structure creates some basic problems for different data systems. The main reason for this is that people in real life applications are hesitant to ask their preferences in any way, in other words, to remain ambiguous and even undecided about the preference level. This uncertainty is not considered in the general fuzzy logic models, so the more intuitionistic fuzzy set theorems which are more comprehensive have been developed.

2.2.1. Intuitionistic Fuzzy Sets

Intuitionistic fuzzy sets can be considered as an extended version of the fuzzy set theory, which better models imperfect knowledge (Atanassov, 1986) and also called as “Type-II Fuzzy Sets”. While membership functions are defined in Type-I fuzzy set as membership and non-membership functions, the situation of hesitation is also taken into consideration in Type-II fuzzy set theory. In many complex decision making problems, the information provided by the decision maker is insufficient and uncertain due to reasons such as time pressure, information inefficiency, or the ability of the decision maker to have limited attention and assessment. For this reason, in many publications it is mentioned that intuitionistic fuzzy sets are a useful solution tool to describe uncertain decision making information fairly well. Intuitionistic fuzzy set theorems are generally used in approximate induction, sample definition and decision making in literature. Xu and Yager (2008) point out that the intuitionistic fuzzy set theory is useful in studies with uncertainty, and they have mentioned that there is a lot of work in the literature for further development of the theory.

Intuitionistic fuzzy sets generally defined as the given equation.

$$A = \langle (x, \mu_A(x), \nu_A(x)) : x \in X \rangle \quad (2.4)$$

Here, $\mu_A(x): X \rightarrow [0,1]$ is defined membership and $\nu_A(x): X \rightarrow [0,1]$ is defined non-membership function. These functions have a property of $0 \leq \mu_A(x) + \nu_A(x) \leq 1$. In this case hesitation is defined with following equation.

$$\pi_A(x) = 1 - \mu_A(x) - \nu_A(x) \quad (2.5)$$

Since the intuitionistic fuzzy sets are the extended versions of the general fuzzy sets, the intuitionistic fuzzy sets become the general fuzzy set theory when the values of hesitation are equal to zero.

Intuitionistic fuzzy set theory can be applied in different fields such as medical diagnosis (De, et al., 2001, Szmidt and Kacprzyk, 2001, 2004), decision making problems (Atanassov et al., 2005; Szmidt and Kacprzyk 2002, 2003, Xu, 2007) and patent recognition (Li and Cheng, 2002; Wang and Xin, 2005; Zhang and Fu, 2006).

Due to the structure of the indicators to be determined, it is very difficult for the preferences to be determined directly and clearly. In other words, the expression of membership functions by a single value both makes the situation more difficult for the decision maker and narrows the scope of the analyses.

2.2.2. Interval valued intuitionistic fuzzy sets

In real life applications, it is a difficult process for the decision maker to pinpoint the degree of membership, uncertainty or hesitation. This is even more impossible, especially when the system under study has a complex structure. Zhai et al. (2017) explained the usage of different forms of fuzzy sets based on the uncertainty level.

In the intuitionistic fuzzy set theory, each choice is basically represented as a single point within the set. On the other hand, the data may be in a structure that cannot be expressed in a single point in terms of uncertainty or complexity, and should be regarded as a range, rather than a single point. For this reason, Atanassov and Gargov (1989) propose to expand the intuitive fuzzy set theory and develop it as a value-interval intuitionistic fuzzy set (IVIFs) theory.

$\tilde{A} = \langle (x, \mu_{\tilde{A}}(x), \nu_{\tilde{A}}(x)) : x \in X \rangle$ where; $IV[0,1]$ represents the closed subsets and $\mu_{\tilde{A}}(x) : X \rightarrow IV[0,1]$ is defined as membership function and $\nu_{\tilde{A}}(x) : X \rightarrow IV[0,1]$ is defined as non-membership function.

In an interval form membership function can be expressed as $\mu_{\tilde{A}}(x) = [\mu_{\tilde{A}_L}(x), \mu_{\tilde{A}_U}(x)]$ and non-membership function can be expressed as $\nu_{\tilde{A}}(x) = [\nu_{\tilde{A}_L}(x), \nu_{\tilde{A}_U}(x)]$. In this case general function is, $\tilde{A} = \langle (x, [\mu_{\tilde{A}_L}(x), \mu_{\tilde{A}_U}(x)], [\nu_{\tilde{A}_L}(x), \nu_{\tilde{A}_U}(x)]) : x \in X \rangle$ and have a property of $0 \leq \mu_{\tilde{A}_U}(x) + \nu_{\tilde{A}_U}(x) \leq 1$.

Interval valued intuitionistic fuzzy (IVIF) sets are generally denoted by $([a, b] ; [c, d])$ for convenience. Let $\widetilde{\alpha}_1 = ([a_1, b_1] ; [c_1, d_1])$ and $\widetilde{\alpha}_2 = ([a_2, b_2] ; [c_2, d_2])$ be any two IVIF sets, then their operational laws can be defined as follows;

$$\bullet \quad \overline{\widetilde{\alpha}_1} = ([c_1, d_1] ; [a_1, b_1]) \quad (2.6)$$

$$\bullet \quad \widetilde{\alpha}_1 + \widetilde{\alpha}_2 = ([a_1 + a_2 - a_1 \cdot a_2, b_1 + b_2 - b_1 \cdot b_2] ; [c_1 \cdot c_2, d_1 \cdot d_2]) \quad (2.7)$$

$$\bullet \quad \widetilde{\alpha}_1 \cdot \widetilde{\alpha}_2 = ([a_1 \cdot a_2, b_1 \cdot b_2] ; [c_1 + c_2 - c_1 \cdot c_2, d_1 + d_2 - d_1 \cdot d_2]) \quad (2.8)$$

$$\bullet \quad \lambda \cdot \widetilde{\alpha}_1 = ([1 - (1 - a_1)^\lambda, 1 - (1 - b_1)^\lambda] ; [c_1^\lambda, d_1^\lambda]) \text{ where } \lambda > 0 \quad (2.9)$$

Xu (2007) proved in his study that all results of following basic operations are also IVIF numbers;

$$\bullet \quad \widetilde{\alpha}_1 + \widetilde{\alpha}_2 = \widetilde{\alpha}_2 + \widetilde{\alpha}_1 \quad (2.10)$$

$$\bullet \quad \widetilde{\alpha}_1 \cdot \widetilde{\alpha}_2 = \widetilde{\alpha}_2 \cdot \widetilde{\alpha}_1 \quad (2.11)$$

$$\bullet \quad \lambda \cdot (\widetilde{\alpha}_1 + \widetilde{\alpha}_2) = \lambda \cdot \widetilde{\alpha}_1 + \lambda \cdot \widetilde{\alpha}_2 \text{ where } \lambda \geq 0 \quad (2.12)$$

$$\bullet \quad \lambda_1 \cdot \widetilde{\alpha}_1 + \lambda_2 \cdot \widetilde{\alpha}_1 = (\lambda_1 + \lambda_2) \cdot \widetilde{\alpha}_1 \text{ where } \lambda_1, \lambda_2 \geq 0 \quad (2.13)$$

In literature, there are several studies for ranking of IVIF numbers. However, generally, score functions and accuracy functions are used (Xu, 2007). Let $\widetilde{\alpha} = ([a, b] ; [c, d])$ be an IVIF number then a score function which is also called net value of the membership will be $S(\widetilde{\alpha}) = \frac{1}{2}(a - c + b - d)$ in a general form where $S(\widetilde{\alpha}) \in [-1, 1]$. If the score function value is high then it means that the related IVIF numbers is greater than other IVIF numbers. Simply, greater score function value indicates the greater IVIF number.

Accuracy functions is another basic ranking method in IVIF numbers which is represented with $H(\widetilde{\alpha}) = \frac{1}{2}(a + b + c + d)$ where $H(\widetilde{\alpha}) \in [0, 1]$. The relationship between score function and accuracy functions is gives the basic ranking procedure. Let $\widetilde{\alpha}_1$ and $\widetilde{\alpha}_2$ be any two IVIF numbers, then the following order relation can be presented.

$$\bullet \quad \text{If } S(\widetilde{\alpha}_1) < S(\widetilde{\alpha}_2), \text{ then } \widetilde{\alpha}_1 < \widetilde{\alpha}_2 \quad (2.14)$$

$$\bullet \quad \text{If } S(\widetilde{\alpha}_1) = S(\widetilde{\alpha}_2), \text{ then accuracy functions are examined s follows;} \\ = \begin{cases} H(\widetilde{\alpha}_1) = H(\widetilde{\alpha}_2) \text{ then } \widetilde{\alpha}_1 = \widetilde{\alpha}_2 \\ H(\widetilde{\alpha}_1) < H(\widetilde{\alpha}_2) \text{ then } \widetilde{\alpha}_1 < \widetilde{\alpha}_2 \end{cases} \quad (2.15)$$

In comparing two IVIF sets, accuracy functions are widely used (Ye, 2009; Nayagam et

al., 2011; Bai, 2013; Joshi, 2015 and Garg, 2016). In each study to generate a better ranking system, several forms for accuracy function is developed. Nyugen (2016) stated that accuracy functions are widely used method in decision-making problems via comparing and ranking the alternatives which are in an IVIF set structure. Main accuracy functions are listed below.

(i) Ye (2009),

$$M(A) = \frac{a-(1-a-c)+b-(1-b-d)}{2} \quad M(A) \in [-1,1] \quad (2.16)$$

(ii) Nayagam et al. (2011),

$$L(A) = \frac{a+b-d(1-b)-c(1-a)}{2} \quad L(A) \in [-1,1] \quad (2.17)$$

(iii) Bai (2013),

$$I(A) = \frac{a+a(1-a-c)+b+b(1-b-d)}{2} \quad I(A) \in [0,1] \quad (2.18)$$

(iv) Joshi (2015),

$$P(A) = \frac{a+b+(a*c)-(b*d)}{3} \quad J(A) \in [-1,1] \quad (2.19)$$

In 2016, Garg stated that studies conducted before are unable to present the appropriate ranking between two IVIF sets. According to the study, Garg suggested to use generalized structure for score function in which it is possible to evaluate the degree of hesitation between membership and non-membership functions. In other terms, in the methodology used by Garg (2016) parameters namely k_1 and k_2 are assigned to the membership and non-membership sets to represent the degree of hesitancy. Increases in the parameter k_1 represents the increased importance to the hesitation degree of membership function whereas the increase in the parameter k_2 represents the increased importance to the hesitation degree of non-membership functions. The changing values of the parameters represent the “attitudinal characters of the generalized improved score function (GIS)” (Garg, 2016). GIS of an IVIF set can be calculated as follows;

$$GIS(A) = \frac{a+b}{2} + k_1 a(1-a-c) + k_2 b(1-b-d) \quad GIS(a) \in [0,1] \text{ where;} \\ k_1 + k_2 = 1 \text{ and } k_1, k_2 \geq 0 \quad (2.20)$$

IVIF sets can be aggregated with a weighted averaging operator defined by Xu (2007). This operator is proven and used in many studies in the literature. Let $w = (w_1, w_2, \dots, w_n)$ be the weight vector n IVIF sets where $\sum_{j=1}^n w_j = 1$ and $w_j \in$

$[0,1]$. The aggregation operator for IVIF sets is derived from an intuitionistic aggregation operation (IFWA) and it is introduced as IIFWA operator which is calculated as follows.

$$\begin{aligned} \text{IIFWA}_w(\tilde{\alpha}_1, \tilde{\alpha}_2, \dots, \tilde{\alpha}_n) = \\ = ([1 - \prod_{j=1}^n (1 - \tilde{\alpha}_j)^{w_j}, 1 - \prod_{j=1}^n (1 - \tilde{b}_j)^{w_j}], [\prod_{j=1}^n \tilde{c}_j^{w_j}, \prod_{j=1}^n \tilde{d}_j^{w_j}]) \end{aligned} \quad (2.21)$$

In many multi criteria decision-making problems, there are several decision makers and their weight are generally different from each other. In such cases, IIFWA operator should be extended to consist of opinions of each decision makers' and merged all individual evaluations into one matrix. In literature, this matrix can be called as aggregation of expert's matrix (Li et al., 2015). Let $R (m \times n)$ is represent the decision maker's evaluation matrix and r_{ij} is an element of this matrix. Suppose that the weight of i^{th} decision maker is known and indicated by λ_i . When the IIFWA adopted, overall evaluation matrix, which consists of every decision makers' opinions, will be calculated as follows.

$$r_{ij} = ([1 - \prod_{k=1}^n (1 - \tilde{\alpha}_k)^{\lambda_k}, 1 - \prod_{k=1}^n (1 - \tilde{b}_k)^{\lambda_k}], [\prod_{k=1}^n \tilde{c}_k^{\lambda_k}, \prod_{k=1}^n \tilde{d}_k^{\lambda_k}]) \quad (2.22)$$

where $\lambda_k \geq 0, i \in 0,1,2 \dots n$ and $\sum_{k=1}^n \lambda_k = 1$

Aggregation of the decision makers' opinions are based on the weight calculation of decision makers'. Let $D_k = [\mu_k, v_k, \pi_k]$ be a fuzzy set for rating the decision makers and λ_k represent the weight of each decision maker. So, weights of decision makers' are calculated as follows;

$$\lambda_k = \frac{(\mu_k + \pi_k (\frac{\mu_k}{\mu_k + v_k}))}{\sum_{k=1}^l (\mu_k + \pi_k (\frac{\mu_k}{\mu_k + v_k}))} \quad (2.23)$$

In the literature, aggregation of the decision makers' opinions is examined in several studies. Different types of aggregation operators are generated and new operations are tried to generate for the extended versions of fuzzy sets.

2.2.3. Probabilistic Linguistic Term Sets

In real life case studies, complexity and uncertainty of the problems cause hesitation in the decision makers' opinions. This situation makes decision-making process more

difficult in terms of determining the opinions of decision makers. Although extended versions of fuzzy sets generally provide a better solution for this problem, still choosing one linguistic term set cannot be possible sometimes. In other terms, decision makers mostly hesitate between choosing the linguistic term sets for their assessments. Rodriguez et al. (2012) stated that the main problem is caused by the vagueness of meaning of the related term sets. They pointed out that the experts or decision makers cannot easily provide their knowledge/information/decision or experience with a single expression since they are thinking of several terms and approaches at the same time. In other terms, not only the provided opinion for membership but also the linguistic term set it has a hesitation.

Rodriguez et al. (2012) suggested using hesitant fuzzy linguistic term sets (HFLTS) to create flexibility in providing linguistic information. According to their study, after collecting of the opinions of decision makers linguistic expressions are transform into HFLTS by using a defined transformation function. Then, all assessments are aggregated and linguistic intervals are created. In the last step, alternatives are ordered to select the best one. In 2014, Beg and Rashid extended the HFLTS and suggested to use TOPSIS for HFLTS. In the study conducted by Pang et al. (2016) current studies about HFLTS are examined and it is stated that in the past studies all possible values provided by decision makers have equal importance. However, it is a well-known fact that this situation does not reflect the real life case study conditions. For that reason, Pang et al. (2016) extended the approach for linguistic term sets and suggested probabilistic linguistic term sets (PLTS) to provide different importance degrees with considering probability. Let $S = \{s_0, s_1, \dots, s_\tau\}$ be a linguistic term set then PLTS can be defined as follows;

$$L(p) = \left\{ L^{(k)}, (p^{(k)}) \mid L^{(k)} \in S, p^{(k)} \geq 0, k = 1, 2, \dots, \#L(p), \sum_{k=1}^{\#L(p)} p^{(k)} \leq 1 \right\} \quad (2.24)$$

Where, $L^{(k)}(p^{(k)})$ is the linguistic term $L^{(k)}$ associated with the probability $p^{(k)}$, and $\#L(p)$ is the number of different linguistic term sets in $L(p)$ (Pang et al., 2016). An ordered PLTS is depend on the subscript ($r^{(k)}$) of linguistic term $L^{(k)}$ and can achieved when the $r^{(k)}p^{(k)}$ values are arranged in the descending order. Before applying the basic operation to PLTS, these sets should be normalized by ignorance of probabilistic

information or by normalizing the cardinality. Pang et al. (2016) analyzed both approaches for normalization and generated a basic formulation. Let assume $L_1(p)$ and $L_2(p)$ be any two PLTS, then the normalization formulas given as follows;

- (1) If $\sum_{k=1}^{\#L(p)} p_i^{(k)} < 1$ then apply $\dot{p}^{(k)} = p^{(k)} / \sum_{k=1}^{\#L(p)} p^{(k)}$ for all $k = 1, 2, \dots, \#L(p)$ and calculate $\dot{L}_i(p)$ for $i = 1, 2$. (2.25)
- (2) If $\#L_1(p) \neq \#L_2(p)$ then add elements to the smaller number of elements set.

In 2016, Pang et al. also studied on the basic operations of PLTS and defined them as follows. Let $L_1(p)$ and $L_2(p)$ be any two ordered and normalized PLTS then;

$$\bullet \quad L_1(p) \oplus L_2(p) = \cup_{L_1^{(k)} \in L_1(p), L_2^{(k)} \in L_2(p)} \{p_1^{(k)} L_1^{(k)} \oplus p_2^{(k)} L_2^{(k)}\} \quad (2.26)$$

$$\bullet \quad L_1(p) \otimes L_2(p) = \cup_{L_1^{(k)} \in L_1(p), L_2^{(k)} \in L_2(p)} \{(L_1^{(k)})^{p_1^{(k)}} \otimes (L_2^{(k)})^{p_2^{(k)}}\} \quad (2.27)$$

$$\bullet \quad \lambda L(p) = \cup_{L^{(k)} \in L(p)} \lambda p^{(k)} L^{(k)}, \lambda \geq 0 \quad (2.28)$$

$$\bullet \quad L(p)^\lambda = \cup_{L^{(k)} \in L(p)} \{L^{(k)} p^{(k)\lambda}\} \quad (2.29)$$

In real life case studies, there are generally several decision makers. In such cases, aggregation of the decision makers' thought is a vital step. In the literature, several studies focused on the generation of aggregation operators (Pang et al., 2016; Lin et al., 2017; Kobina et al., 2017; Liu et al., 2017; Malik et al., 2018). Let $L_i^{(k)}$ and $p_i^{(k)}$ represents the k^{th} linguistic term and its probability thus probabilistic linguistic averaging (PLA) operator and probabilistic weighted averaging (PLWA) operator are calculated as follows;

$$\bullet \quad PLA(L_1(p), L_2(p), \dots, L_i(p)) = \frac{1}{n} (L_1(p) \oplus L_2(p) \oplus \dots \oplus L_n(p)) \quad (2.30)$$

$$\bullet \quad PLWA(L_1(p), L_2(p), \dots, L_i(p)) = (w_1 L_1(p) \oplus w_2 L_2(p) \oplus \dots \oplus w_n L_n(p)) \text{ where } w = (w_1, w_2, \dots, w_n)^T \text{ and } \sum_{i=1}^n w_i = 1 \quad (2.31)$$

After collecting and aggregated the decision makers' opinions, determination of attribute weights is become the most important issue in a decision-making problem. Normalized formulation for weight determination of attributes are given as follows where i represents the alternatives j represents the attributes and detailed information can be found in Pang et al. (2016) study.

$$w_j = \frac{\sum_{i=1}^m \sum_{q \neq i} \sqrt{\frac{1}{\#L_{ij}(p)} \sum_{k=1}^{\#L_{ij}(p)} (p_{ij}^{(k)} r_{ij}^{(k)} - p_{qj}^{(k)} r_{qj}^{(k)})^2}}{\sum_{j=1}^n \sum_{i=1}^m \sum_{q \neq i} \sqrt{\frac{1}{\#L_{ij}(p)} \sum_{k=1}^{\#L_{ij}(p)} (p_{ij}^{(k)} r_{ij}^{(k)} - p_{qj}^{(k)} r_{qj}^{(k)})^2}} \quad j = 1, 2, \dots, n \quad (2.32)$$

In the recent years, probabilistic linguistic term sets are started to use widely and more extended form generated in which hesitation of membership and non-membership functions also included. In 2017, Lin et al. used probabilistic uncertain linguistic term sets and integrated these sets with TOPSIS methodology. Malik et al. (2018) also examined on the uncertainty of probabilistic linguistic sets and applied in a multi-criteria decision making problem. In 2018, Xingli and Huchang used PLTS with quality function deployment methodology for multi-expert criteria decision making.

In this study, probabilistic linguistic terms sets are used for the determination of attribute weights (Severity, Preventability and Occurrence/Frequency). Although the extended versions of linguistic terms sets which generated in the last years is started use in several cases, mathematical background of these extended versions have to be studied more. For that reason, probabilistic linguistic terms sets that are defined by Pang et al. (2016) is chosen to be used in this study and the calculation procedure for weight determination of attributes is based on the formulas that are firstly presented by Pang et al. (2016) as well.

2.3. Similarity and Distance Measurements

Zhai et al. (2017) stated the importance of measurement in their study and indicated that there are basic three most common kinds of measures, distance measures, similarity measures and entropy measures. In solving decision making problems these measurements are vital to find the difference among elements. Especially for fuzzy sets, different forms of measure are generated for IFs and IVIFs (Zhai et al., 2017).

Similarity and distance measures are used for the calculation of closeness and dissimilarity between two sets. In literature there are several studies about the similarity measurement of fuzzy sets since these measurements are very important especially for a specific kind of problems such as pattern recognition, decision making etc. Cha (2007) stated that as a scientific definition, distance represent the quantitative degree of how far apart two sets are on the other hand similarity include proximity. Yet, deciding on the

appropriate distance / similarity measures only depends on the structure of the studied sets or representation of objects.

Basic similarity measures between fuzzy sets are proposed by several studies such as Chen (1996), Hsieh (1999), Chen and Chen (2003), Deng Yong (2004) and Shi-Jay Chen (2006). However, there are a substantial number of distance / similarity measures as mentioned by Cha (2007). In the following section, distance and similarity measurements are detailed.

2.3.1. Interval valued intuitionistic fuzzy distance measurements

Distance generally defined as a measure to determine the difference between two sets or two elements of the same set. Papakostas et al. (2013) stated that a distance d in a nonempty set A is a real function $d: A \times A \rightarrow [0, +\infty)$ which satisfies the conditions below,

- C1: $\forall x, y, z \in A \Rightarrow d(x, y) = 0 \Leftrightarrow x = y$ (coincidence)
- C2: $\forall x, y, z \in A \Rightarrow d(x, y) = d(y, x)$ (symmetry)
- C3: $\forall x, y, z \in A \Rightarrow d(x, z) + d(z, y) \geq d(x, y)$ (triangle inequality)

In literature, several distance measures are proposed (Atanossov, 1986; Szmidt and Kacprzyk, 2000; Wang and Xin, 2005; Grzegorzewski, 2004; Chen, 2007; Yang and Chiclana, 2012). Let $A = \{ \langle x_j, \tilde{\mu}_A(x_j), \tilde{\nu}_A(x_j) \rangle | x_j \in X \}$ and $B = \{ \langle x_j, \tilde{\mu}_B(x_j), \tilde{\nu}_B(x_j) \rangle | x_j \in X \}$ are subsets of universal set X and let $\tilde{\mu}_A(x_j) = [\tilde{\mu}_A^L(x_j), \tilde{\mu}_A^U(x_j)]$, $\tilde{\mu}_B(x_j) = [\tilde{\mu}_B^L(x_j), \tilde{\mu}_B^U(x_j)]$, $\tilde{\nu}_A(x_j) = [\tilde{\nu}_A^L(x_j), \tilde{\nu}_A^U(x_j)]$, $\tilde{\nu}_B(x_j) = [\tilde{\nu}_B^L(x_j), \tilde{\nu}_B^U(x_j)]$. Main forms of distance measures are listed as follows;

(i) Hamming Distance

$$d_H(A, B) = \sum_{i=1}^n |\Delta_{\mu}(i)| \text{ thus;}$$

$$d_H(A, B) = \frac{1}{4} \sum_{j=1}^n [|\tilde{\mu}_A^L(x_j) - \tilde{\mu}_B^L(x_j)| + |\tilde{\mu}_A^U(x_j) - \tilde{\mu}_B^U(x_j)| + |\tilde{\nu}_A^L(x_j) - \tilde{\nu}_B^L(x_j)| + |\tilde{\nu}_A^U(x_j) - \tilde{\nu}_B^U(x_j)|] \quad (2.33)$$

(ii) Normalized Hamming Distance

$$d_{nH}(A, B) = \frac{1}{n} \sum_{i=1}^n |\Delta_{\mu}(i)| \text{ thus;}$$

$$d_{nH}(A, B) = \frac{1}{4n} \sum_{j=1}^n [|\tilde{\mu}_A^L(x_j) - \tilde{\mu}_B^L(x_j)| + |\tilde{\mu}_A^U(x_j) - \tilde{\mu}_B^U(x_j)| + |\tilde{\nu}_A^L(x_j) - \tilde{\nu}_B^L(x_j)| + |\tilde{\nu}_A^U(x_j) - \tilde{\nu}_B^U(x_j)|]$$

$$|\tilde{v}_B^L(x_j)| + |\tilde{v}_A^U(x_j) - \tilde{v}_B^U(x_j)| \quad (2.34)$$

(iii) Euclidean Distance

$$d_E(A, B) = \sqrt{\sum_{i=1}^n (\Delta_\mu(i))^2} \text{ thus;}$$

$$d_E(A, B) = \sqrt{\frac{1}{4} \sum_{j=1}^n \left[\left(\tilde{\mu}_A^L(x_j) - \tilde{\mu}_B^L(x_j) \right)^2 + \left(\tilde{\mu}_A^U(x_j) - \tilde{\mu}_B^U(x_j) \right)^2 + \left(\tilde{v}_A^L(x_j) - \tilde{v}_B^L(x_j) \right)^2 + \left(\tilde{v}_A^U(x_j) - \tilde{v}_B^U(x_j) \right)^2 \right]} \quad (2.35)$$

(iv) Normalized Euclidean Distance

$$d_{nE}(A, B) = \sqrt{\frac{1}{n} \sum_{i=1}^n (\Delta_\mu(i))^2} \text{ thus;}$$

$$d_{nE}(A, B) = \sqrt{\frac{1}{4n} \sum_{j=1}^n \left[\left(\tilde{\mu}_A^L(x_j) - \tilde{\mu}_B^L(x_j) \right)^2 + \left(\tilde{\mu}_A^U(x_j) - \tilde{\mu}_B^U(x_j) \right)^2 + \left(\tilde{v}_A^L(x_j) - \tilde{v}_B^L(x_j) \right)^2 + \left(\tilde{v}_A^U(x_j) - \tilde{v}_B^U(x_j) \right)^2 \right]} \quad (2.36)$$

Atanassov (1986) generalized these basic forms of distance measurements by adding them the non-membership value v . In 2000, Szmidt and Kacprzyk proposed the modified versions of measures with including hesitation π . Thus, basic forms of mentioned distance measurements turn to appropriate form for interval valued intuitionistic fuzzy sets. These modified forms of measurements are as follows.

(i) Hamming Distance

$$d_H^2(A, B) = \frac{1}{2} \sum_{i=1}^n \{ |\Delta_\mu(i)| + |\Delta_\nu(i)| + |\Delta_\pi(i)| \} \quad (2.37)$$

(ii) Normalized Hamming Distance

$$d_{nH}^2(A, B) = \frac{1}{2n} \sum_{i=1}^n \{ |\Delta_\mu(i)| + |\Delta_\nu(i)| + |\Delta_\pi(i)| \} \quad (2.38)$$

(iii) Euclidean Distance

$$d_E^2(A, B) = \sqrt{\frac{1}{2} \sum_{i=1}^n \left[(\Delta_\mu(i))^2 + (\Delta_\nu(i))^2 + (\Delta_\pi(i))^2 \right]} \quad (2.39)$$

(iv) Normalized Euclidean Distance

$$d_{nE}^2(A, B) = \sqrt{\frac{1}{2n} \sum_{i=1}^n \left[(\Delta_\mu(i))^2 + (\Delta_\nu(i))^2 + (\Delta_\pi(i))^2 \right]} \quad (2.40)$$

In many studies in the literature, similarity measures are based on the distance measures. Zhai et al. (2017) stated that the utility of the distance measures are depending on the

differences of two compared sets since it is quite opposite of similarity measurements in which coincidence degree is emphasized. In other terms, similarity measures are also considered practical tools to define the relation between sets. However, in most of the measurement formula, the hesitation degree is not considered properly and this situation causes some illogical results in some cases. Wu et al. (2014) stated in their study that measurements considering the hesitation degree outperform the current methodologies. Moreover, using these measurements provide well-considered group decisions.

2.3.2. Interval valued intuitionistic fuzzy similarity measurements

Similarity measurements are one of the most important and popular topics of fuzzy theory since they can be used in a wide range of issues. In 2007, Li et al. stated in their study that a similarity measures between two sets should satisfy the following conditions. $S(A, B)$ is said to be the degree of similarity between sets A and B since;

- P1: $S(A, B) \in [0, 1]$
- P2: $S(A, B) = 1 \Leftrightarrow A = B$ (coincidence)
- P3: $S(A, B) = S(B, A)$ (symmetry)
- P4: $S(A, C) \leq S(A, B)$ and $S(A, C) \leq S(B, C)$ if $A \subseteq B \subseteq C$ (triangle inequality)
- P5: $S(A, B) = 0 \Leftrightarrow A = \Phi$ and $B = \bar{A}$ or $A = \bar{B}$ and $B = \Phi$

In literature, there are several forms of similarity calculations since each researcher tried to overcome the problems and irrational cases that are seen on the previous measurements. In 2012, Singh conducted a study in which existing similarity measures summarized and according to the study, there are basically seven similarity measurements for IFs. Let $\tilde{A}$ and $\tilde{B}$ be two IF sets in the universe of discourse $X = x_1, x_2, \dots, x_n$. Thus, similarity measures are listed as follows;

(i) Chen (1995, 1997)

$$S_C(\tilde{A}, \tilde{B}) = 1 - \frac{\sum_{i=1}^n |S_{\tilde{A}}(x_i) - S_{\tilde{B}}(x_i)|}{2n} \text{ where;}$$

$$S_{\tilde{A}}(x_i) = \mu_{\tilde{A}}(x_i) - \nu_{\tilde{A}}(x_i) \text{ and } S_{\tilde{B}}(x_i) = \mu_{\tilde{B}}(x_i) - \nu_{\tilde{B}}(x_i) \quad (2.41)$$

In Chen's proposed measures $S_{\tilde{A}}(x_i) \in [-1, 1]$; $S_{\tilde{B}}(x_i) \in [-1, 1]$ and the bigger $S_C(\tilde{A}, \tilde{B})$ value means that sets A and B are more similar. On the other hand, when $A = \{(x, 0, 0)\}$ and $B = \{(x, 0.5, 0.5)\}$ the value of S_C equals to 1 which means that set A

is same as set B . This situation is irrational since it leads to series of cases in which $\mu_{\tilde{A}}(x_i) - v_{\tilde{A}}(x_i) = \mu_{\tilde{A}}(x_i) - v(x_i)$.

(ii) Hong and Kim (1999);

$$S_H(\tilde{A}, \tilde{B}) = 1 - \frac{\sum_{i=1}^n (|\mu_{\tilde{A}}(x_i) - \mu_{\tilde{B}}(x_i)| + |v_{\tilde{A}}(x_i) - v_{\tilde{B}}(x_i)|)}{2n} \quad (2.42)$$

This measure is mainly focus on the difference between membership and non-membership values of two sets. However, the main problem of the mentioned measure is it cannot distinguish positive difference from negative difference since absolute value is used in all calculations.

(iii) Fan and Zhangyan (2001);

$$S_L(\tilde{A}, \tilde{B}) = 1 - \frac{\sum_{i=1}^n |\mu_{\tilde{A}}(x_i) - \mu_{\tilde{B}}(x_i)|}{4n} - \frac{\sum_{i=1}^n (|\mu_{\tilde{A}}(x_i) - \mu_{\tilde{B}}(x_i)| - |v_{\tilde{A}}(x_i) - v_{\tilde{B}}(x_i)|)}{4n} \quad (2.43)$$

In this similarity measure, although problems that are mentioned in both (i) and (ii) are tried to overcome and gives more reasonable solutions, there are still counterintuitive cases.

(iv) Yanhong et al. (2002);

$$S_O(\tilde{A}, \tilde{B}) = 1 - \sqrt{\frac{\sum_{i=1}^n (\mu_{\tilde{A}}(x_i) - \mu_{\tilde{B}}(x_i))^2 + (v_{\tilde{A}}(x_i) - v_{\tilde{B}}(x_i))^2}{2n}} \quad (2.44)$$

Calculation of $S_O(\tilde{A}, \tilde{B})$ value is emphasizing difference between membership and non-membership values of two sets however as it is seen on the calculation of $S_H(\tilde{A}, \tilde{B})$, measure cannot distinguish positive difference from negative difference and causes irrational situations.

(v) Dengfeng and Chuntian (2002);

$$S_{DC}(\tilde{A}, \tilde{B}) = 1 - \sqrt[p]{\frac{\sum_{i=1}^n |\Psi_{\tilde{A}}(x_i) - \Psi_{\tilde{B}}(x_i)|^p}{n}} \text{ where} \quad (2.45)$$

$$\Psi_{\tilde{A}}(x_i) = \frac{(\mu_{\tilde{A}}(x_i) + 1 - v_{\tilde{A}}(x_i))}{2} \text{ and } \Psi_{\tilde{B}}(x_i) = \frac{(\mu_{\tilde{B}}(x_i) + 1 - v_{\tilde{B}}(x_i))}{2}$$

In the calculation of $S_{DC}(\tilde{A}, \tilde{B})$ values, first step is converting the sets A and B into ordinary fuzzy sets $\Psi_{\tilde{A}}(x_i)$ and $\Psi_{\tilde{B}}(x_i)$ after that simple Minkowski distance is applied. However, this measure has the same problem with (i) since it turns to same equation when $p=1$. In 2003, Mitchell made simple modification to $S_{DC}(\tilde{A}, \tilde{B})$ calculation with adding statistical view however; the case turns to mentioned problem in (ii).

(vi) Liang and Shi (2003);

$$S_e^p(\tilde{A}, \tilde{B}) = 1 - \sqrt[p]{\frac{\sum_{i=1}^n |\varphi_{\tilde{\mu}}(x_i) - \varphi_{\tilde{\nu}}(x_i)|^p}{n}} \text{ where}$$

$$\varphi_{\tilde{\mu}}(x_i) = \frac{|\mu_{\tilde{A}}(x_i) + 1 - \mu_{\tilde{B}}(x_i)|}{2} \text{ and } \varphi_{\tilde{\nu}}(x_i) = \left| 1 - \frac{(\nu_{\tilde{A}}(x_i))}{2} - \frac{(1 - \mu_{\tilde{B}}(x_i))}{2} \right| \quad (2.46)$$

To overcome the problems of (v), measure focuses on the end-points of the subintervals. In other words, calculation focuses differences between membership and non-membership values as well as differences between median values of intervals or subintervals.

(vii) Xu et al. (2008)

$$X_U(\tilde{A}, \tilde{B}) = \frac{\sum_{i=1}^n (\mu_{\tilde{A}}(x_i) \cdot \mu_{\tilde{B}}(x_i)) + (\nu_{\tilde{A}}(x_i) \cdot \nu_{\tilde{B}}(x_i)) + (\pi_{\tilde{A}}(x_i) \cdot \pi_{\tilde{B}}(x_i))}{\max(\sum_{i=1}^n (\mu_{\tilde{A}}^2(x_i) + \nu_{\tilde{A}}^2(x_i) + \pi_{\tilde{A}}^2(x_i)), \sum_{i=1}^n (\mu_{\tilde{B}}^2(x_i) + \nu_{\tilde{B}}^2(x_i) + \pi_{\tilde{B}}^2(x_i)))} \quad (2.47)$$

Similarity measures for IVIFs are also an important topic since they are widely used to estimate the degree of similarity between two sets. Xu and Chen (2008) generalized the formulas of similarity measures for IVIFs. As it is stated in Zhai et al.'s study (2017), current definitions mostly focused on three-dimensional structure and consider the uncertainty.

Let $\tilde{A}$ and $\tilde{B}$ be two IVIF sets where $\tilde{A} = \{(x_j, [u_{\tilde{A}}^-(x_j), u_{\tilde{A}}^+(x_j)], [v_{\tilde{A}}^-(x_j), v_{\tilde{A}}^+(x_j)]) | x_j \in X\}$ and $\tilde{B} = \{(x_j, [u_{\tilde{B}}^-(x_j), u_{\tilde{B}}^+(x_j)], [v_{\tilde{B}}^-(x_j), v_{\tilde{B}}^+(x_j)]) | x_j \in X\}$ thus similarity measures are listed as follows;

(i) Xu (2007)

$$S_1(\tilde{A}, \tilde{B}) = 1 - \frac{1}{4} \sum_{j=1}^n w_j [|u_{\tilde{A}}^-(x_j) - u_{\tilde{B}}^-(x_j)| + |u_{\tilde{A}}^+(x_j) - u_{\tilde{B}}^+(x_j)| + |v_{\tilde{A}}^-(x_j) - v_{\tilde{B}}^-(x_j)| + |v_{\tilde{A}}^+(x_j) - v_{\tilde{B}}^+(x_j)|] \quad (2.48)$$

$$S_2(\tilde{A}, \tilde{B}) = 1 - (\frac{1}{4} \sum_{j=1}^n w_j [(u_{\tilde{A}}^-(x_j) - u_{\tilde{B}}^-(x_j))^2 + (u_{\tilde{A}}^+(x_j) - u_{\tilde{B}}^+(x_j))^2 + (v_{\tilde{A}}^-(x_j) - v_{\tilde{B}}^-(x_j))^2 + (v_{\tilde{A}}^+(x_j) - v_{\tilde{B}}^+(x_j))^2])^{1/2} \quad (2.49)$$

$$S_3(\tilde{A}, \tilde{B}) = 1 - \sum_{j=1}^n w_j \max \{|u_{\tilde{A}}^-(x_j) - u_{\tilde{B}}^-(x_j)|, |u_{\tilde{A}}^+(x_j) - u_{\tilde{B}}^+(x_j)|, |v_{\tilde{A}}^-(x_j) - v_{\tilde{B}}^-(x_j)|, |v_{\tilde{A}}^+(x_j) - v_{\tilde{B}}^+(x_j)|\} \quad (2.50)$$

$$S_4(\tilde{A}, \tilde{B}) = 1 - (\sum_{j=1}^n w_j \max \{(u_{\tilde{A}}^-(x_j) - u_{\tilde{B}}^-(x_j))^2, (u_{\tilde{A}}^+(x_j) - u_{\tilde{B}}^+(x_j))^2, (v_{\tilde{A}}^-(x_j) - v_{\tilde{B}}^-(x_j))^2, (v_{\tilde{A}}^+(x_j) - v_{\tilde{B}}^+(x_j))^2\})^{1/2}$$

$$v_B^-(x_j))^2, (v_A^+(x_j) - v_B^+(x_j))^2\}^{1/2} \quad (2.51)$$

(ii) Wei et al. (2011)

$$M(\tilde{A}, \tilde{B}) = \{ \langle [u_{M(A,B)}^-(x), u_{M(A,B)}^+(x)], [v_{M(A,B)}^-(x), v_{M(A,B)}^+(x)] \rangle | x \in X \} \text{ where;}$$

(2.52)

$$u_{M(A,B)}^-(x) = \min\{M_{AB1}(x), M_{AB2}(x)\},$$

$$u_{M(A,B)}^+(x) = \max\{M_{AB1}(x), M_{AB2}(x)\},$$

$$v_{M(A,B)}^-(x) = \min\{M_{AB3}(x), M_{AB4}(x)\},$$

$$v_{M(A,B)}^+(x) = \max\{M_{AB3}(x), M_{AB4}(x)\}. \text{ In this case;}$$

$$M_{AB1}(x) = \frac{1 + \min\{|u_A^-(x) - u_B^-(x)|, |v_A^-(x) - v_B^-(x)|\}}{2}$$

$$M_{AB2}(x) = \frac{1 + \min\{|u_A^+(x) - u_B^+(x)|, |v_A^+(x) - v_B^+(x)|\}}{2}$$

$$M_{AB3}(x) = \frac{1 - \max\{|v_A^-(x) - u_B^-(x)|, |v_A^-(x) - v_B^-(x)|\}}{2}$$

$$M_{AB4}(x) = \frac{1 - \max\{|u_A^+(x) - u_B^+(x)|, |v_A^+(x) - v_B^+(x)|\}}{2}$$

According to similarity calculation which is proposed by Wei et al. (2011), similarity between A and B IVIF sets is $S(\tilde{A}, \tilde{B}) = E(M(\tilde{A}, \tilde{B}))$. Here “E” is represents the entropy measure on IVIFs and calculated as follows;

$$E = \frac{1}{n} \sum_{j=1}^n (\min\{u_A^-(x), v_A^-(x)\} + \min\{u_A^+(x), v_A^+(x)\} + \pi_A^-(x) + \pi_A^+(x)) * \\ (\max\{u_A^-(x), v_A^-(x)\} + \max\{u_A^+(x), v_A^+(x)\} + \pi_A^-(x) + \pi_A^+(x))^{-1} \quad (2.53)$$

(iii) Wu et al. (2014)

$$M(\tilde{A}, \tilde{B}) = \{ \langle [u_{M(A,B)}^-(x), u_{M(A,B)}^+(x)], [v_{M(A,B)}^-(x), v_{M(A,B)}^+(x)] \rangle | x \in X \} \text{ where;}$$

(2.54)

$$u_{M(A,B)}^-(x) = \min\{M_{AB1}(x), M_{AB2}(x)\},$$

$$u_{M(A,B)}^+(x) = \max\{M_{AB1}(x), M_{AB2}(x)\},$$

$$v_{M(A,B)}^-(x) = \min\{M_{AB3}(x), M_{AB4}(x)\},$$

$$v_{M(A,B)}^+(x) = \max\{M_{AB3}(x), M_{AB4}(x)\}. \text{ In this case;}$$

$$M_{AB1}(x) = \frac{2 + |u_A^-(x) - u_B^-(x)| + |v_A^-(x) - v_B^-(x)| - |\pi_A^+(x) + \pi_B^+(x)|}{4}$$

$$M_{AB2}(x) = \frac{2 + |u_A^+(x) - u_B^+(x)| + |v_A^+(x) - v_B^+(x)| - |\pi_A^-(x) + \pi_B^-(x)|}{4}$$

$$M_{AB3}(x) = \frac{2 - |u_A^-(x) - u_B^-(x)| + |v_A^-(x) - v_B^-(x)| - |\pi_A^+(x) + \pi_B^+(x)|}{4}$$

$$M_{AB4}(x) = \frac{2 - |u_A^+(x) - u_B^+(x)| + |v_A^+(x) - v_B^+(x)| - |\pi_A^-(x) + \pi_B^-(x)|}{4}$$

According to similarity calculation which is proposed by Wu et al. (2014), similarity between A and B IVIF sets is $S(\tilde{A}, \tilde{B}) = E(M(\tilde{A}, \tilde{B}))$. Here “E” is represents the entropy measure on IVIFs as well. Based on the given entropy calculations it is possible to rearrange similarity formula as follows;

$$S(\tilde{A}, \tilde{B}) = \frac{1}{n} \sum_{j=1}^n \frac{4 - (u_j^- + u_j^+ + v_j^- + v_j^+) + (\pi_j^- + \pi_j^+)}{4 + (u_j^- + u_j^+ + v_j^- + v_j^+) + (\pi_j^- + \pi_j^+)} \text{ where;} \quad (2.55)$$

$$u_j^- = |u_A^-(x_j) - u_B^-(x_j)|, \quad u_j^+ = |u_A^+(x_j) - u_B^+(x_j)|,$$

$$v_j^- = |v_A^-(x_j) - v_B^-(x_j)|, \quad v_j^+ = |v_A^+(x_j) - v_B^+(x_j)|,$$

$$\pi_j^- = |\pi_A^-(x_j) + \pi_B^-(x_j)|, \quad \pi_j^+ = |\pi_A^+(x_j) + \pi_B^+(x_j)|.$$

In this study, calculations of the similarity values are repeated by applying all mentioned methodologies during the analysis of the collected data. However, final calculations depend on the measurement system that is generated by Wu et al. in 2014. The underlying reason is the structure of the Wu et al. (2014) methodology in which hesitation is considered more properly than the other methodologies. Wu et al. (2014) stated that entropy measurements are used to construct the similarity measures in other studies as well. On the other hand, these mentioned studies such as Wei et al. (2011) can cause problems especially when the difference between the membership and non-membership values of the evaluated dataset and the value of compared fuzzy set is so close to each other. The other case that problems occur is about the large difference between the hesitation value of the evaluated set and the compared set. Wu et al. (2014) considered the hesitation degree and the influence of the related values to handle these mentioned problems. In their study, they also proved the efficiency of their proposed methodology by comparing other methodologies in the literature.



3. PATIENT SAFETY MANAGEMENT MODEL

Patient safety is considered as one of the key dimensions of the hospital quality improvement systems in Turkey. In “Standards of Accreditation in Health” report, which is published by Ministry of Health in Turkey in 2015, patient safety is directly related as an objective of several standards. Although regulations emphasized the importance of patient safety, it is stated that health institutions within the scope of regulation are obliged to carry out their own internal regulations and measures in order to provide the necessary activities to ensure patient and employee safety. However, healthcare institutions can create their own internal regulations and follow-up plans on patient safety. While this is beneficial for the dissemination of patient safety cultures, it poses difficulties in terms of auditing. The lack of a standard patient safety system for the evaluation of medical errors causes a great variation in terms of provided service quality levels among hospitals. Therefore, it is clear that there is a need an effective, systematic and standardized system.

3.1. Problem Definition

In the published regulation about the protection of patient and employee safety in 2011, patient safety practices are listed to provide safe service provision for patients and health employee in all health institutions. The main aim is regulating the procedures and principles to increase the quality level in health systems via determining possible risks for patients and employees. In the regulation, patient focused safety practices are listed as follows;

- Identification and verification of patient identity information,
- Taking consent of the patient for the procedures to be applied to the patient,
- Ensuring communication security in health service delivery,
- Providing medicine safety,
- Ensuring transfusion safety of blood and blood products,
- Ensuring surgical safety,
- Prevention of patient falls,
- Ensuring radiation safety,
- Making arrangements for disabled patients.

In addition to this mentioned patient focused practices, health institutions are held responsible to the establishment of safety reporting system. According to the regulation, safety reporting system should include the medication safety, transfusion safety, surgical safety; patient falls etc. and the corrective and preventive actions should be taken for reported events. Although the regulation emphasized the importance of patient safety, it is stated that health institutions within the scope of this regulation are obliged to carry out their own internal regulations and measures in order to provide the necessary activities to ensure patient and employee safety. In simple terms, each health institution needs to establish their methodology to provide patient safety. However, the lack of a standard patient safety system for the evaluation of medical errors causes a great variation in terms of provided service quality levels among hospitals.

The differences in data structure and the integration of these data into each other, creates a necessity for the uncertainty analysis. In general, most of the ambiguity is because of the doubt for correct diagnosis and for the proper treatment. However, even if the correct treatment is chosen, uncertainties remain about whether the patient will respond to treatment or complications will occur. In every medical intervention, even if it is maintained correctly, there has a possibility of error, complication (calculated risk) and adverse effect share, depending on the underlying cause. It is not possible to completely eliminate the risk of medical intervention but it is necessary to weight the risks before decision stage. In practice, it is not clear in most cases that the underlying cause of an undesirable outbreak is the nature of the medical illness, or an error, or the result of an unsuccessful medical process. Moreover, it is also possible that these two different situations occur at the same moment. The greatest challenge in the healthcare process is the need to have very different quality data and to handle many different dimensions at the same time. The process is human-focused and this variation in the data makes the system's structure very complex.

3.2. Current State of the System

Safety reporting system is a platform that health institutions and professionals can report medical errors thus they can inform with common errors and precautions of these errors. In Figure 3.1, departments that a medical error can occur and the connection between these departments according to error types is presented.

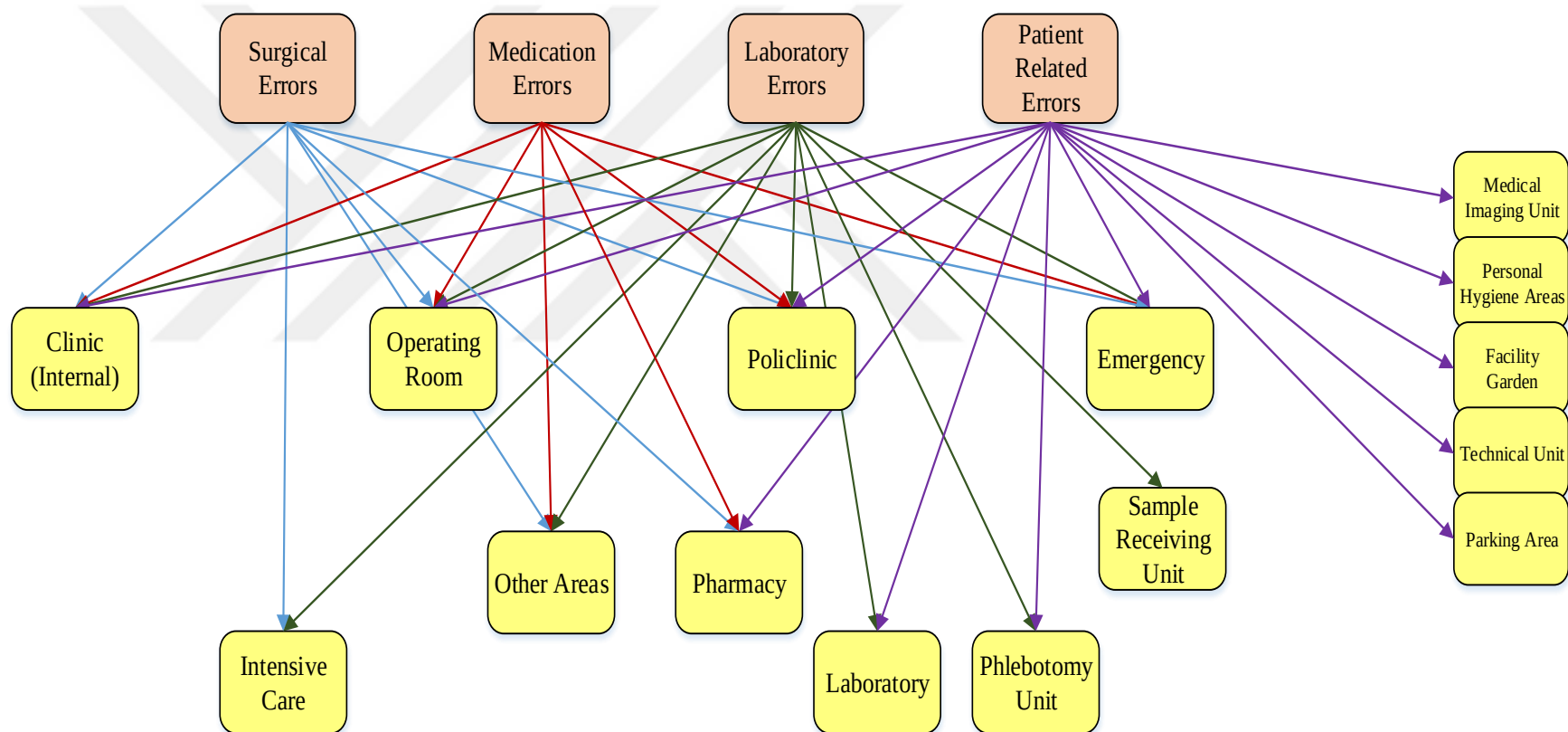


Figure 3.1. Places that a medical error can occur (Adapted from Ministry Of Health, Safety Reporting System, 2017)

In safety reporting system, medical errors are classified into four main categories such as laboratory, medication, general/ surgical and patient centered errors. In each category there are also several sub-categories based on the procedure of the related system. In Table 3.1., laboratory related medical errors are presented. In this category, errors are separated into three sub-category taking into account the laboratory processes. These categories are included medical errors that can occur during pre-analytic (PR), analytic (AN) and post-analytic (PO) processes.

Table 3.1. Laboratory errors, explanations and codes

Main Category	Sub-Category	Code	Error Type
LABORATORY	PR	L01	Wrong test request
		L02	Missed/wrong information in test request
		L03	Unorganized pathology request form
		L04	Unrecorded sample
		L05	Wrong record
		L06	Sampling from the wrong patient
		L07	Incorrect sample identification
		L08	Missing sample
		L09	Recollected sample
		L10	Incorrect sample container/tube
		L11	Empty sample container/tube
		L12	Samplig with expired tubes
		L13	Not barcoded sample
		L14	Cancellation of the record because a sample could not be obtained from the patient
		L15	Inappropriate taken sample
		L16	Insufficient sample
		L17	Sample with hemolysis
		L18	Clotted sample
		L19	Lipemic sample
		L20	Icteric sample
		L21	Unsent sample in fixative
		L22	Time of sampling is not saved
		L23	Undelivered sample in the laboratory
		L24	Inappropriate transfer conditions
		L25	Exceeding the determined maximum transfer duration of the sample
		L26	Mixing of samples
		L27	Acceptance of the samples that should be rejected
		L28	Automation failure
		L29	Inappropriate stored sample
		L30	Determination of expired kit
		L31	Determination of expired material
		L32	Requested material/kit is not arrived

Table 3.1 (continued)

		L33	Arrived material/kit is wrong
		L34	Inappropriate material transfer conditions
		L35	Inappropriate stored material
		L36	Inappropriate temperature of laboratory
		L37	Undone device maintenance
		L38	Inappropriate preparation of medium
	AN	L28	Automation failure
		L39	Equipment failure
		L40	Equipment strawing failure
		L41	Insufficient homogenization of the sample
		L42	Failure to follow test procedures
		L43	Seeding failure
		L44	Nonconformity of external quality control studies
		L45	Working with improper quality control outputs
		L46	Not working with internal quality control
		L47	Inappropriate incubation temperature
		L48	Inappropriate incubation period
		L49	Inappropriate pigmentation technique
		L50	Improper dilution
		L51	Using improper solution
		L52	Incorrect evaluation of the result
		L53	Incorrect technical approval
	PO	L05	Wrong record
		L28	Automation failure
		L54	Incorrectly entered report results
		L55	Incorrect report
		L56	Unsaved patient reports
		L57	Results that are not given in time
		L58	Lately reported panic value

According to the report published by Ministry of Health, 234.746 errors for pre-analytic category, 24.886 errors for analytic and 8.039 errors for post-analytic category are reported via safety reporting system in 2016. After the reported error are examined, it is observed that “L18- Clotted sample”, “L17- Sample with hemolysis”, “L16- Insufficient sample”, “L28- Automation failure during pre-analytic process” and “L01- Wrong test request” are the top five medical errors. Report also focused on the time interval and the department that error occurred. Analysis revealed that most of the laboratory related errors are occurred at polyclinic and emergency department during 08.00-12.00 time intervals.

In general, totally 74.383 error reports were made to safety reporting system in 2016. %93,82 (69.782) of these reports constitute laboratory related errors. The underlying

reason for this conclusion is directly related the reporting culture. In other words, error reporting and follow-up structure is considered as a basic part of the laboratory systems so this situation explains the encountered results.

The second main category in the safety reporting system is included medication related medical errors which are given in Table 3.2. in detail. Medication errors mostly reviewed as a drug safety issue in the current literature. According to the Ministry of Health safety reporting system, in medication related errors, there are six sub-categories, which represent all the steps of medication safety. These mentioned categories are, Storage (I0), Demand (I1), Preparation (I2), Transfer (I3), Implementation (I4) and Post-implementation (I5) respectively.

Table 3.2. Medication errors, explanations and codes

Main Category	Sub-Category	Code	Error Type
MEDICATION	I0	a	Inappropriate temperature and humidity
		b	Violation of FIFO rule
		c	Light exposure
		d	Confusion in selection because of the similarity in writing, reading or appearance of the drugs
		e	Pediatric doses are on the same shelf with other drugs
		f	Failure in controlling of critical stock level
		g	Faulty expiration date and critical stock level warning system
		h	Undefined high-risk drugs
		i	Undefined psychotropic and narcotic drugs
		j	Stolen drugs
		k	Loss of drugs
		l	Expired drugs
	I1	a	Wrong drug demand
		b	Wrong drug selection in electronic system
		c	Choosing wrong treatment
		d	Writing contraindicated drugs
		e	Using abbreviation in drug name
		f	Illegible handwriting
		g	Erroneous dosing
		h	Misunderstanding of verbal demand
		i	Unwritten verbal demand
		j	Lack of communication
	I2	a	Misinterpretation of doctor's demand
		b	Preparation of wrong drug
		c	Incorrect packaging of drugs
		d	Incorrect labelling of drugs
		e	Undefined medicines that brought by the patient
		f	Unimplemented hand hygiene

Table 3.2. (continued)

		g	Drug incompatibility
		h	Preparing the medicine with the wrong technique
		i	Confusion in selection because of the similarity in writing, reading or appearance of the drugs
		j	Incorrect labelling of prepared drugs
		k	Drug application without doctor request
		l	Unauthorized drug application
		m	Impaired drug application
		n	Presence of medication near the patient
		o	Inaccurate information about the use of medicine
		p	Not informing the patient about the use of the medicine
	I3	a	Prepared medicines sent to the wrong patient
		b	Distribution of drugs at the wrong time
		c	Transferring wrong drug from pharmacy
		d	Wrong delivery of medicines
		e	Do not send drugs to patients / department on time
	I4	a	Unimplemented hand hygiene
		b	Failure to comply with sterilization / disinfection rules
		c	Wrong patient
		d	Wrong drug
		e	Wrong dosage (high)
		f	Wrong dosage (low)
		g	Wrong pharmaceutical form
		h	Wrong time
		i	Wrong methodology
		j	Applying incompatible drugs at the same time
		k	Skipping a dosage
		l	Repeated drug administration
		m	Incorrect application period (Injection)
		n	Incorrect application period (Infusion)
	I5	a	No hand hygiene after drug application
		b	Drug application not recorded
		c	Non-removal of wastes after drug application
		d	No observations after drug administration
		e	Adverse effect (management not defined)
		f	Adverse effect (Notification)
		g	Not observed drug-drug, drug-food interaction
		h	Original packaging of the returned medicine is broken

According to the published safety system report (2016), 1.119 errors for storage, 5.132 errors for demand, 2.307 errors for preparation, 997 error for transfer, 1.227 errors for implementation and 379 errors for post-implementation are reported. Top five errors were “I1g- Erroneous dosing”, “I1a-Wrong drug demand”, “I1j- Lack of communication”, “I2b-Preparation of wrong drug” and “I3c-Transferring wrong drug

from pharmacy”. Detailed analysis of the error reports are revealed that, medication related medical errors are generally occurred between 08.00-12.00 time interval and mostly seen at clinics (%66,52) and pharmacies (%18,43). When the results of the reported errors are examined, another remarkable point is revealed. Although there is a prevention system in the current healthcare system, still “I1b- Wrong drug selection in electronic system”, “I1f-Illegible handwriting” and “I1i- Unwritten verbal demand” errors are reported.

The third main category in the safety reporting system is included general/surgical errors which are given in Table 3.3. in detail. In the general/surgical errors category there are 8 sub-categories. These are (i) Clinical surgical procedure preparation (C1), (ii) Transfer to the operating room and patient acceptance(C2), (iii) Operating room surgical procedure(C3), (iv) Pre-anesthesia preparation and control(C4), (v) Controls before surgery(C5), (vi) Follow up and control during operation(C6), (vii) Controls at the end of the operation (C7) and (viii) Departure of the patient from the operation room and transfer (C8).

Table 3.3. General/Surgical errors, explanations and codes

Main Category	Sub-Category	Code	Error Type
GENERAL/ SURGICAL	C1	di	Non-marking of operation area / side
		ik	Not controlling marking of the operation area / side
		ac	Pre-op fasting requirement not confirmed
		tr	The operation area has not been shaved
		gd	Not confirming removal of make-up, prosthesis and valuable items
		oi	Skipping pre-operative special procedure (enema application etc.)
		mk	Failure to control supply of supplies and blood / blood products for surgery
		tk	Do not check that examination and surveys are near the patient
		oa	Not receiving patient's consent
		ok	Not controlling the received patient's consent
	C2	kd	Unverified Patient ID, location of operation and surgical procedure
		te	Health worker does not accompany patient transfer
		ta	Do not deliver the patient to the health worker
		ti	Failure to transmit information about the operation during delivery
	C3	at	Failure of cleaning of operation room and surgical table
		ak	Not controlling of anesthesia devices and equipment
		ck	Equipment malfunction due to lack of calibration / maintenance
		gk	Do not check that the outlets are connected to uninterruptible power supply

Table 3.3. (continued)

		pk	Not performing particle counting / checking
		sn	Inadequate control of room temperature and humidity
		tg	Not controlling the medical gas system
	C4	kd	Unverified Patient ID, location of operation and surgical procedure
		ok	Not controlling the received patient's consent
		ik	Not controlling marking of the operation area / side
		po	Pulse oximeter device not on patient and not controlled
		ad	Unevaluated allergy status
		kk	Not evaluating the necessity of blood transfusion
		gc	Not controlling the display devices that may be needed
		hd	Unresolved anesthesia risks
	C5	kd	Unverified Patient ID, location of operation and surgical procedure
		et	Team members do not identify themselves
		kc	Critical events that can occur due to surgery are not evaluated
		ka	Unevaluated critical event that can occur due to anesthesia
		sk	Do not check that the materials are ready and sterile
		cp	Not applying the required surgical prophylaxis
		ks	Unevaluated blood sugar control necessity
		ko	Unquestioning of the use of anticoagulants
		vp	Do not apply the required DVT prophylaxis
	C6	ku	No patient compliance check when blood / blood product use is required
		pf	No appropriate labeling of the sample when frozen is required
	C7	gi	Unverified Patient ID, location of operation and surgical procedure
		ta	Uncontrolled instrument, sponge, compress and needle counts that are used
		pe	Not properly labelled receipt samples
		cg	Unrecognized possible surgical critical care requirements
		ag	Potential anesthesia critical maintenance requirements not assessed
		gy	Not specifying the part of the post-op patient to be transferred
	C8	gb	Failure to transmit surgical critical care requirements to healthcare personnel who receives the patient
		kd	Patient identity, surgical procedure and the part of the patient to be transferred are not verified
		ta	Do not deliver the patient to the health worker
		ts	Health worker does not accompany patient transfer

According to the published safety system report (2016), 680 errors for C1, 135 errors for C2, 61 errors for C3, 107 errors for C4, 61 errors for C5, 19 errors for C6, 62 errors for C7 and 32 errors for C8 are reported. Top five errors were “di-Non-marking of operation area / side”, “kd-Unverified Patient ID, location of operation and surgical procedure”, “gd-Not confirming removal of make-up, prosthesis and valuable items”, “tr-The operation area has not been shaved” and “ts-Health worker does not accompany patient transfer”. Detailed analysis of the error reports are revealed that, surgical errors are

generally occurred between 08.00-12.00 time interval and mostly seen at clinics (%40,88) and operation rooms (%25,67).

The final main category in the safety reporting system is included patient related errors which are given in Table 3.4. in detail with 8 sub-categories. These are (i) Physical Structure Related (BYH), (ii) Device/Equipment/System Related (CSH), (iii) Medical Record and Clinic Evaluation Related (TKH), (iv) Communication Error (ILH), (v) Care, Diagnosis and Treatment Process Related (BTH), (vi) Patient/ Attendant Related (HRH), (vii) Errors Concerning the Transfusion of Blood and Blood Products (KTH) and (viii) Errors Regarding Nutrition (NIH).

Table 3.4. Patient related errors, explanations and codes

Main Category	Sub-Category	Code	Error Type
PATIENT BASED	BYH	a	Patient stuck in the elevator due to the malfunction
		b	Patient fall/injured due to the elevator malfunction
		c	Patient fall/injured due to the escalator malfunction
		d	Patient fall/injured due to the slippery floors
		e	The absence of a disaster and emergency plan
		f	Lack of emergency and disaster management guidance
		g	Missing /Not found patient instruction marks
		h	Lack of elderly or disabled patient instructions
		i	Medical gas contamination or incorrect gas mixture
		j	Injured patients due to the electric leakage
		k	Injured patients due to the fire /explosion
		l	Contamination of water resources
		m	Flood / Sewage flood
		n	Exposure to hazardous waste /material except for diagnosis / treatment purposes
		o	Absence of noise control in the intensive care unit
		p	Basic facility resource related backup systems didn't started in time
	CSH	a	Injured patient due to the movement restriction equipment
		b	Unprovided asepsis conditions due to the lack of infrastructure / equipment
		c	Untimely repaired / replaced defective equipment
		d	Untimely made device calibration and /or tests
		e	Lack of care, diagnosis and treatment process related equipment
		f	Injured patient due to the device failure
		g	Lack of internal safety or sentinel event reporting system
		h	Untimely interfere to the sentinel event notifications
		i	Not evaluated internal safety report notifications
		j	Failure to provide training about the emergency and disaster management
		k	Not evaluated patient complaints and feedbacks

Table 3.4. (continued)

		l	Loss of patient information data because of the safety problem in information network
		m	Stolen patient information data because of the safety problem in information network
		n	Patient Fall
	TKH	a	Incorrect identification of patients
		b	Delivering someone else's receipt to the patient
		c	Wrong delivery of the newborn
		d	Incorrect handling of medical records about the applied care or treatment
		e	Illegible evaluation / consultations notes
		f	Missing / Wrong evaluation / consultations notes
		g	Incorrect record of patient basic information
	ILH	a	Uninformed patient about the care, diagnosis method or treatment
		b	Missing/ Lack of information about the care, diagnosis method or treatment
		c	Care and treatment after hospitalization
	BTH	a	Complication developed in the patient due to maintenance / treatment delay
		b	Complication developed in the patient due to consultation delay
		c	Patient care plan not determined according to patient needs
		d	No evaluation of the patient in terms of nutrition
		e	No asepsis / sterilization / isolation requirements for care
		f	Misassignment of assay and test results
		g	Confirmation of patient identity before treatment / care
		h	Patient Fall
		i	Unsuitable patient delivery
		j	Late intervention for blue code status
		k	Late intervention in pink code condition
		l	Late intervention in red code condition
		m	Infringement of patient privacy
		n	Patient safety not provided
		o	Application with medical device filled with calibration period
		p	Formation of 3rd level and higher pressure ulcer in patient in hospitalization period
		q	Late detection of hyperbilirubinemia in the newborn
		r	Late detection of hypoglycemia in the newborn
		s	Late detection of premature retinopathy in the newborn
		t	Giving the wrong blood / blood product to the patient
		u	Failure to provide the necessary protective equipment to the patient during medical imaging
		v	Not monitoring of complications developing after care or treatment
	HRH	a	Suicide attempt resulting in serious injury or death
		b	The patient's health condition causes harm to other patients
		c	Patient Falls
		d	The patient does not follow the care / treatment guidelines in the hospitalization process
		e	Removal / replacement of the identity by the patient without informing healthcare professional
		f	Changing the bed without the healthcare provider's knowledge

Table 3.4. (continued)

		g	Use of medication / nutrition / food supplement without the healthcare staff's knowledge
		h	The patient does not fulfill preoperative requirements
		i	Departure from the health facility without the knowledge of the hospital's health personnel
		j	Providing incomplete / misleading information about the patient's health histories
		k	The refusal of compulsory education by the patient or accompanying persons
		l	Formation of 3rd level pressure after the discharge
		m	The patient does not come to control after discharge
		n	The patient does not follow post-discharge care / treatment guidelines
	KTH	a	Not confirmed patient identity
		b	Lack of records of transfusion request
		c	Not checking product information (Blood group, Cross-match, SKT, Tests etc.)
		d	Product label information is incorrect
		e	Incorrect transfer of blood product
		f	Incorrect application of blood product
		g	Failure to observe patients properly before and after the procedure
	NIH	a	Not evaluated nutritional status of the patient
		b	Unquestioned food allergy story of the patient
		c	Improper nutritional support or diet choice for the patient
		d	Giving the wrong food to the patient
		e	Food brought to the patient from outside the facility
		f	Food poisoning
		g	Inadequate nutrition of the patient during treatment
		h	Overfeeding of the patient during the treatment process
		i	Incorrect preparation of PN suspension
		j	Incorrectly protected PN suspension
		k	Incorrect application of PN suspension
		l	PN suspension given to the wrong patient
		m	Maintenance-induced TPN catheter infection
		n	Not informing the patient about nutrition while being discharged

According to the published safety system (2016), 156 physical structure related errors, care, 286 diagnosis and treatment process related errors, 271 patient / attendant related errors, 73 communication related errors, 138 device/equipment/system related errors and 189 medical record and clinic evaluation related errors are reported. Top errors were “HRHc- Patient Falls”, “TKHc- Incorrect record of patient basic information” and “TKHa- Incorrect identification of patients”. Detailed analysis of the error reports are revealed that, patient related errors are generally occurred between 08.00-12.00 time interval and mostly seen at clinics (%59,96) and policlinics (%10,42).

3.3. Proposed Patient Safety Index Model

In order to ensure patient safety, a standard system is needed to measure the factors that threaten patient safety. Focusing the incidents one by one is not only a time consuming system but also highly depends on the human oriented mechanisms. Moreover, the underlying reason of the need for a standard patient safety system is providing the reliability of the measurement system before determining regulatory and preventive actions to ensure patient safety.

Management of patient safety is required a comprehensive model therefore it is planned to generate an index system in which all medical errors are evaluated in terms of severity, preventability and occurrence/frequency criteria. Health institutions can be evaluated based on this index system since the occurrence/frequency of the error is only related with the evaluated health institution thus each error will have a unique score. After a unique score for each error is determined for the evaluated health institution, these scores are used to create index values. It is possible to create an index value in the level of each error, each department or each health institution. Moreover, these values can also be used to create a prioritization for the improvements in health institution and provide a continuous development cycle.

In the following parts, each step of the proposed model is presented with detail explanations. To calculate the overall index value for each error, the initial step is the weighting the attributes. After that, an index value is calculated via considering the frequency of the error in the determined time interval if the related error recorded in the health institutions previously. However, an importance value for each error is also calculated even if the related error never occurred in the health institutions. The underlying reason is taking precautions for errors in a systematic way. In other terms, the fact that an error has not occurred before, does not mean that related error will not occur later. For this reason, system should consider every dimension and preventive mechanisms should be taken into account if it is necessary. Thus, it is possible to evaluate the general position of the health institutions with a proactive view of point.

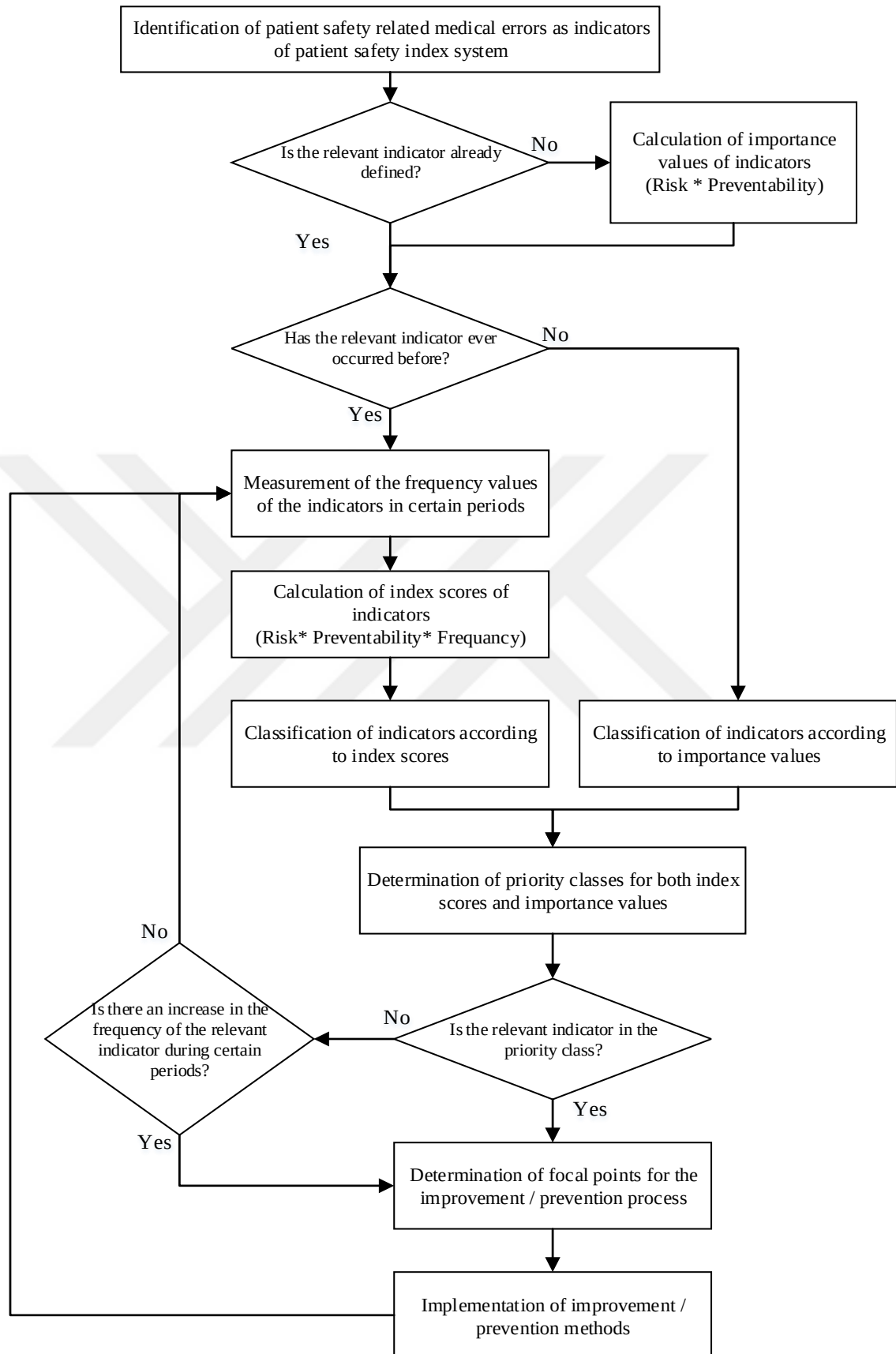


Figure 3.2. Proposed patient safety index methodology

This study is applied in a private hospital, which is one of the biggest health institutions in Turkey. Selected health institution, which is one of the mostly known private hospital in Turkey, is already accredited by Joint Commission International (JCI). JCI accredits eight types of health care programs: hospitals, academic medical center hospitals, ambulatory care facilities, clinical laboratories, home care facilities, long term care facilities, medical transport organizations, and primary care centers. Commission works to improve patient safety and quality of health care in the international community by offering education, publications, advisory services, and international accreditation and certification. In 2011, international patient safety goals by commission are determined as follows.

- Goal 1: Identify patients correctly
- Goal 2: Improve effective communication
- Goal 3: Improve the safety of high alert medications
- Goal 4: Ensure correct-site, correct-procedure, correct-patient surgery
- Goal 5: Reduce the risk of health care associated infections
- Goal 6: Reduce the risk of patient harm from falls.

JCI is an independent organization which aims to develop the concepts of quality improvement and patient safety and to increase the efficiency of healthcare services while providing objective evaluation tools for this purpose. In other terms, if a health institution is accredited by JCI, the related health institution is already provided requirements for safety reporting mechanism and safety culture. In this regard, Frequency/occurrence values for errors are taken from quality improvement department of the health institution.

In the initial stages of this study, errors are collected with some paper-based documents in the health institution. In these documents, it is asked from the health employee, who is reporting the error, to state the category of the related error and its consequences over the patient(s). After documents are collected, evaluation process is started in the quality department one by one. In the evaluation, risk of the error is determined and needed future actions are planned. These future state improvements are reported to the related department, where the reported error occurs, and if future state reports include process-based improvements further analysis is asked from the department. Finally, related

information in the initial document and future state reports are archived in the computer via scanning the documents to create further reports at the end of the year. In current system, steps of the error reporting and evaluation process is same however, electronic system is started to use for reporting errors instead of paper-based documents.

There are vital problems in the current error reporting and evaluation system in the mentioned healthcare institution. Although, the problems in the collection of error reports are reduced after starting to use electronic system, core problems remain in the evaluation process.

- After collecting the error reports it is not possible to response rapidly since quality department should examine all reports one by one to determine the priority of issues. This situation causes long waiting times for the solutions of preventions of some errors and meanwhile same error can be occurred.
- Process highly depends on the knowledge of the related employees in the quality department. The main reason is that first evaluations whether the error is catastrophic or minor made by them. This employee dependent process not only causes long process times but also is highly possible to decide in a wrong way. Additionally, it is possible to decide different risk categories for the same problem, which occurs in different times, by different employees. This causes a new kind of a problem.
- Since the risk category of the related error is decided based on the knowledge of the employee, department needs too much qualified employees. However, there is still a chance to give a wrong priority to errors that directly affects the improvement process.
- Improvement process is based on the core decision of the risk category of the related error. After the category is chosen, department plans regulatory and preventive actions. From this point of view, a mistake that can be occur in the first processes can directly affect the rest of the system. Moreover, preventive actions are generally taken based on the related error one by one; however, different errors can be caused by the same problem in the system. For that reason, systematic analysis is needed.

Problems in the current state of the system prove that there is a need for a standard system in the evaluations of safety errors. The main point is eliminating the employee dependent decisions to make a more systematic analysis. A systematic evaluation of the

safety situation in health institution can be achieved with a proper prioritization among errors. The results of the evaluation and prioritization process will be an input for the systematic improvement stages. In the rest of the study, each step of the proposed model is explained in detail and the results are presented for the selected health institution.

3.3.1. Weight determination of attributes

Patient safety index is a comprehensive model and main structure of the model is highly depends on the selecting and weighting the attributes. For that reason as an initial step, weight determination methodology, which consists of Severity, Preventability and Occurrence/Frequency, is generated and probabilistic linguistic term sets are used to determine the weights of these attributes.

Weight determination for Severity, Preventability and Occurrence/Frequency criteria is also a complex process for that reason it should be considered and implemented as a separated model. Hybrid multi criteria decision-making model is generated to determine the weights since the structure of the data is uncertain and imperfect information is inevitable. Steps of the proposed weight determination methodology are presented in the sub-parts.

Step 1: Analyze the actual problem and determine the set of attributes

It is not possible to completely eliminate the risk of medical intervention but it is necessary to weight the risks before decision stage. For that reason, after a review of risk management literature and occupational health and safety regulations, attributes for the patient safety mechanism are selected as Severity, Preventability and Occurrence/Frequency.

Severity represents the impact of the damage to be caused in terms of related error on patient or health employee. In other terms, it is the degree of risk of the related error. In the general index system, severity will also be evaluated for each error in the scale from “no harm to the patient” to “causes death of a patient”. Preventability represents how to prevent the errors before they reach the patient or healthcare worker and when preventability of each error is evaluated in the index system, scale is changed from “easily preventable” to “not preventable”. Details of each scaling system will be presented in the next parts. Finally, occurrence/frequency represents the number of occurred events for a specific error in an institution (the number of patients or health care

workers). In the general index system, occurrence/frequency score of the related error is used directly after normalization of the value since the occurrence/frequency is a unique score for each health institution.

In the initial step of the index system, only the weights of the basic three attributes are calculated. The underlying reason is that it is not possible to create an index score for an error without weighting the attributes. For example, wrong drug delivery is a common error among patient safety related errors. Consequences of this error can be quite important (severity level-error can cause death) however it can prevent easily (preventability level-error can prevent with a simple method). On the other hand, in some institutions because of the lack of employee trainings or lack of control mechanisms, the error occurred frequently. In such a case, importance of attributes should be examined firstly to determine the importance level of the mentioned error for further improvements. Only after the weights of the attributes are calculated, an index score can be found for the related error.

Step 2: Collection of decision makers' opinions

Decision makers' are asked to provide their opinions about the attributes; severity, preventability and occurrence/frequency. Firstly, decision makers' are informed about the importance of patient safety then each attribute is explained in detail in terms of patient safety. A sample of the applied electronic evaluation document is presented in Appendix 1a (English version) and 1b (Turkish version).

In rating, decision makers evaluate the impact level of the related attribute in evaluating errors based on their experiences and believe via using the following probabilistic linguistic term set.

$S =$

$\{S_0 = \text{No importance}, S_1 = \text{Extremely low importance}, S_2 = \text{Very low importance}, S_3 = \text{Low importance}, S_4 = \text{Medium – Low importance}, S_5 = \text{Medium importance}, S_6 = \text{Medium – High importance}, S_7 = \text{High importance}, S_8 = \text{Very high importance}, S_9 = \text{Extremely high importance}, S_{10} = \text{Absolute importance} \}$

Opinions of the decision makers are collected via using an electronic evaluation form. In

the first part of the related document, decision makers rate the importance level of the attributes. The answer(s) that they provided represent which attribute is more important when compared to other attributes in terms of patient safety. In the form, it is mandatory to provide at least one rating on the other hand; it is possible to define different opinions as well. For that reason, the same question is asked for three times and an empty space is also provided if they have more answers than three.

In the second part of the evaluation form, they are asked to score their importance ratings which are determined in the first part of the document. The answer to this question represents the strength of their view of specified ratings. For example, if they have only 1 rating, then the score they need to give to the 1st rating should be 100 out of 100 and others should be 0. On the other hand, if they have made 2 or 3 evaluations, they should distribute the overall score between different ratings. It is expected that giving a higher score to a rating represents that the decision maker is more accurate about the related rating.

An electronic evaluation form, which is used to collect decision makers' opinions, is applied during August 2018-November 2018. Evaluation form is sent not only the selected health institution but also sent to all levels of health employee especially to doctors and nurses. Totally, 138 answers are collected; %42 of the participants' specified three different ratings, %20 of them provide two different ratings and finally %38 of them provide only one rating.

Step 3: Aggregation of decision makers' opinions

In healthcare systems, the greatest challenge is the need to have very different quality data and to handle many different dimensions at the same time. For that reason, collection of opinions from different decision makers' is essential. After collecting the data in step 1, results are aggregated and presented in Table 3.5.

Table 3.5. Aggregated Ratings

	$r^{(k)}$	$p^{(k)}$		
		SEVERITY	PREVENTABILITY	OCCURRENCE
S_0	0	0.000	0.000	0.004
S_1	1	0.035	0.115	0.229
S_2	2	0.158	0.270	0.284
S_3	3	0.214	0.229	0.275
S_4	4	0.207	0.118	0.113
S_5	5	0.166	0.172	0.053
S_6	6	0.105	0.079	0.038
S_7	7	0.069	0.018	0.004
S_8	8	0.046	0.000	0.000
S_9	9	0.000	0.000	0.000
S_{10}	10	0.000	0.000	0.000

In this study, decision makers' are thought to be in the same level thus they are not weighted however further studies decision makers' can also weighted based on their experiences and job title.

Aggregated results are normalized, then final aggregation results are achieved and these results are presented in the Table 3.6. in which linguistic terms are ordered based on the rule that is given in the preliminaries part of the study according to their probabilistic values that are determined with the aggregation equations.

Table 3.6. Normalized Aggregated Ratings

Severity								
Linguistic Term	S_5	S_4	S_3	S_6	S_7	S_8	S_2	S_1
$r^{(k)}$	5	4	3	6	7	8	2	1
$p^{(k)}$	0.166	0.207	0.214	0.105	0.069	0.046	0.158	0.035
$r^{(k)} * p^{(k)}$	0.831	0.828	0.642	0.630	0.482	0.368	0.316	0.035
Preventability								
Linguistic Term	S_5	S_3	S_2	S_6	S_4	S_7	S_1	S_5
$r^{(k)}$	5	3	2	6	4	7	1	5
$p^{(k)}$	0.172	0.229	0.270	0.079	0.118	0.018	0.115	0.000
$r^{(k)} * p^{(k)}$	0.859	0.686	0.539	0.475	0.473	0.124	0.115	0.000
Occurrence								
Linguistic Term	S_3	S_2	S_4	S_5	S_1	S_6	S_7	S_3
$r^{(k)}$	3	2	4	5	1	6	7	3
$p^{(k)}$	0.275	0.284	0.113	0.053	0.229	0.038	0.004	0.000
$r^{(k)} * p^{(k)}$	0.826	0.569	0.452	0.263	0.229	0.225	0.031	0.000

Step 4: Weight calculation for attributes

After collecting and aggregating the decision makers' opinions, determination of attribute weights become the most important issue in a decision-making problem. For each attribute, overall weights are calculated and these weights are used in next parts.

Normalized formulation for weight determination of attributes is used and a final weight for each attribute is achieved. According to final calculation, weights are determined as **0.387**; **0.334** and **0.279** for severity, preventability and occurrence/frequency respectively. Attribute weights are the input for the calculation of index scores for patient safety related errors.

3.3.2. Calculation of Index Values

In the proposed patient safety management model, an index score should be calculated for each error. Steps of the proposed index value calculation methodology are presented in sub-parts.

Step 1: Determination of attribute scales

In every decision-making problem attributes can be changed based on the structure of the actual problem and applications in real life cases. In healthcare management especially for patient safety attributes are determined as severity, preventability and occurrence/frequency as it is stated. Attributes should be evaluated for each error to calculate an overall score for the related health institution based on a determined scaling. In this study, after a detailed literature review, scales for each attribute is determined as presented in Table 3.7. and 3.8.

Table 3.7. Preventability Scale (Karasan et al., 2018)

Code	Definition
1	Easily Preventable (control charts etc.)
2	Can be preventable with small system improvements
3	Can be preventable with trainings
4	Can be preventable with radical improvements
5	Unpreventable but side effects can be preventable
6	Unpreventable

Preventability represents how to prevent the errors before they reach the patient or healthcare worker. In traditional risk assessment methodologies this attribute is generally

considered as detectability.

Table 3.8. Severity Scale (Adapted from Touwen et al., 2007)

Code Definition

LI	Grade 0: Without repercussion for the patient (near miss)
MLI	Grade 1: The adverse events contributed to temporary harm to the patient and intervention was needed
MI	Grade 2: Contributed to temporary harm to the patient thereby resulting in longer admission was necessary
I	Grade 3: Contributed to or resulted in permanent harm to patient
VI	Grade 4: Intervention was needed to keep the patient alive
EI	Grade 5: Contributed to the death of the patient

Severity represents the impact of the damage to be caused in terms of related error on patient or health employee. In other terms, it is the degree of risk of the related error. For severity and preventability calculations, linguistic terms scales which is presented in Table 3.9. is used.

Table 3.9. Linguistic Term Scale for Preventability and Severity (Oztaysi et al., 2017)

Linguistic Term (Code)		Membership Values (μ)	Non-Membership Values (ν)
Preventability	Severity	$(\mu^L; \mu^U)$	$(\nu^L; \nu^U)$
1	EI	(0.65 ; 0.75)	(0.1 ; 0.25)
2	VI	(0.60 ; 0.70)	(0.15 ; 0.30)
3	I	(0.55 ; 0.65)	(0.20 ; 0.35)
4	MI	(0.50 ; 0.60)	(0.25 ; 0.40)
5	MLI	(0.45 ; 0.55)	(0.30 ; 0.45)
6	LI	(0.25 ; 0.40)	(0.50 ; 0.60)

Occurrence/frequency represents the number of occurred events for a specific error in an institution (the number of patients or health care workers). In the determination of occurrence/frequency scale, risk management literature is investigated however generally in risk assessment matrices are not suitable for healthcare systems. For that reason Paling Perspective Scale is adapted and used in occurrence/frequency scale. Related scale is explained in the methodology part in detail.

Table 3.10. Occurrence/Frequency Scale (Paling, 2003)

Code	Defintion
Rare	Less than 1 in 100,000,000 (probability of being $x < 0.00000001$)
Very Low	1 in 100,000,000 (probability of being $0.00000001 < x < 0.0000001$)
Low	1 in 10,000,000 (probability of being $0.0000001 < x < 0.000001$)
Medium-Low	1 in 1,000,000 (probability of being $0.000001 < x < 0.0001$)
Medium	1 in 100,000 (probability of being $0.00001 < x < 0.0001$)
Medium High	1 in 10,000 (probability of being $0.0001 < x < 0.001$)
High	1 in 1,000 (probability of being $0.001 < x < 0.01$)
Very High	1 in 100 (probability of being $0.01 < x < 0.1$)
Extrenely High	1 in 10 (probability of being $0.1 < x < 1$)

For occurrence/frequency calculations, lingusitic terms scales which is presented in Table 3.10. is used. The main reason is using different linguistic term scale in occurrence/frequency calculations because of the structure of equations that are going to use in prioritization calculations. In other terms, importance weight calculations which only consist of severity and preventability attributes to make a prioritization list accuracy formulation are used thus the scale should not consist of zero values. However, in the index value calculations performance of the related health institution is considered and similarity equations are used which are allowed to use zero values as well.

Table 3.11. Linguistic Term Scale for Preventability and Severity (Onar et al., 2015)

Linguistic Term for Occurrence/Frequency	Membership Values (μ)	Non-Membership Values (ν)
	$(\mu^L ; \mu^U)$	$(\nu^L ; \nu^U)$
Rare	(0 ; 0.2)	(0.5 ; 0.8)
Very Low	(0.1 ; 0.3)	(0.4 ; 0.7)
Low	(0.2 ; 0.4)	(0.3 ; 0.6)
Medium-Low	(0.3 ; 0.5)	(0.2 ; 0.5)
Medium	(0.4 ; 0.6)	(0.2 ; 0.4)
Medium High	(0.5 ; 0.7)	(0.1 ; 0.3)
High	(0.6 ; 0.8)	(0 ; 0.2)
Very High	(0.7 ; 0.9)	(0 ; 0.1)
Extrenely High	(0.8 ; 1)	(0 ; 0)

In the proposed index system, occurrence/frequency score of the related error is used directly after normalization of the number of patient values since the occurrence/frequency is a unique score for each health institution. For the normalization, actual number of patient visits for the related health institution is considered. The observation period is one year however it is divided two 6-months period to make more detailed analysis and compare the periods. Number of patient visits for the first period is 435,717 and 422,826 for the second period.

Step 2: Collection of decision makers' opinions

Decision makers' are asked to provide their opinions about each error in terms of the attributes; severity and preventability. Firstly, decision makers' are informed about the importance of patient safety then each attribute is explained in detail in terms of patient safety. In rating, decision makers evaluate the severity and preventability level of the related error based on their knowledge and experiences via using determined IVIFs linguistic term sets. Opinions of the decision makers are collected via using an electronic evaluation form. A sample of the applied electronic evaluation document is presented in Appendix 2a (English version) and 2b (Turkish version).

An electronic evaluation form, which is used to collect decision makers' opinions, is applied for 5 month period (June 2018-October 2018). Evaluation form is sent not only the selected health institution but also sent to all levels of health employee especially to doctors and nurses. Totally, 134 answers are collected however 12 of them eliminated because of the missing data. Finally, 122 answers are collected from all levels of health employee and evaluated in the study. A sample of evaluation for laboratory errors is presented in Table 3.12. In the following tables, evaluations are given in the code form.

Table 3.12. Sample evaluation form with coded values for laboratory errors

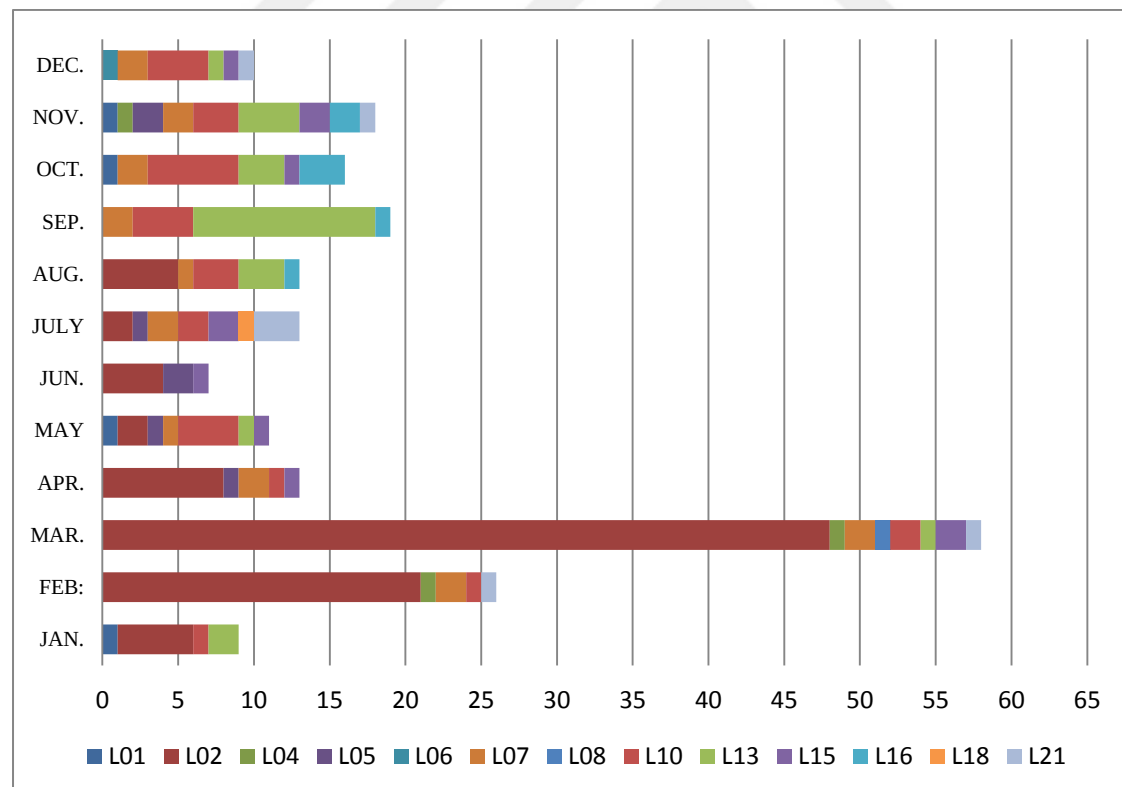
	1		2		3		4		5		6		7		8		9		10		...	50		51		52		53		54		55		56		...	115	116	117	118	119	120	121	122									
	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	...	S	P	S	P	S	P	S	P	S	P	S	P	S	P	...	S	P	S	P	S	P	S	P	S	P	S	P					
L01	3	2	1	1	1	2	1	1	2	3	3	3	3	2	2	2	2	1	3	1	...	3	1	1	1	2	1	1	1	3	1	3	1	3	1	...	1	1	1	1	2	3	3	1	3	3	3	2	1	1	3	3	
L02	3	2	2	2	1	2	1	2	4	3	4	4	3	2	3	3	3	1	3	2	...	3	2	3	2	1	2	3	2	1	2	4	2	4	3	...	4	2	1	2	3	2	4	2	3	2	1	2	3	2	3	2	
L03	4	3	2	2	2	3	2	3	3	2	4	4	3	1	6	4	6	1	3	2	...	3	3	4	3	1	4	4	4	1	1	6	2	1	3	...	6	1	4	2	3	3	2	2	4	3	3	1	1	3	2	3	
L04	3	2	1	3	2	3	3	2	3	2	1	2	1	2	4	4	4	1	3	2	...	3	4	1	4	1	3	3	1	4	2	1	2	3	2	...	3	3	1	2	1	1	3	2	1	2	1	2	1	2	2	4	
L05	4	3	2	3	2	3	1	3	4	4	3	4	1	2	6	4	6	1	1	2	...	2	1	1	3	1	4	4	3	3	2	2	4	1	3	...	1	3	1	3	3	2	4	3	3	3	1	2	1	3	4	4	
L06	6	3	4	4	2	3	2	2	4	1	4	4	3	2	2	2	2	1	1	2	...	3	2	2	2	2	3	4	4	1	2	2	2	1	2	...	2	2	2	1	3	2	1	3	4	4	1	2	6	3	2	2	
L07	6	4	4	4	2	3	3	3	3	2	1	2	3	2	6	5	6	1	3	2	...	3	2	6	2	1	4	6	3	3	4	4	3	4	2	...	3	1	6	4	1	5	1	2	6	2	4	2	3	2	1	4	
L08	3	3	3	3	2	2	3	3	3	2	1	2	1	1	3	3	3	2	3	2	...	3	2	3	1	3	2	1	3	3	1	3	2	3	3	...	3	1	3	2	3	2	3	2	1	2	1	3	2	2	3	3	
L09	2	3	1	2	2	3	3	3	3	2	3	5	1	3	1	2	1	5	3	3	...	2	3	2	5	3	2	1	2	1	1	2	5	3	2	...	1	3	3	3	3	2	3	2	3	5	3	3	3	5	3	1	
L10	2	3	2	3	2	3	1	3	4	3	1	3	1	2	1	2	1	6	3	3	...	3	3	2	2	5	2	5	2	4	3	1	3	2	3	...	1	6	1	3	1	2	1	6	1	2	2	3	4	3	1	3	
L37	4	2	2	3	2	2	3	2	4	4	4	3	1	1	2	2	2	3	1	1	...	1	3	4	3	1	2	1	2	2	3	3	2	4	3	...	2	2	3	2	1	1	2	4	2	4	4	3	2	2	4	1	
...																																																					
L49	4	3	2	4	2	3	3	5	4	3	1	3	3	3	3	4	3	2	1	3	...	2	2	2	4	2	3	3	3	2	3	1	4	4	3	...	4	3	3	5	1	2	2	3	2	2	3	3	2	5	2	5	
L50	4	2	2	4	2	3	3	3	4	4	1	3	3	1	3	4	3	4	1	3	...	1	3	3	1	4	3	3	3	4	4	3	4	2	4	...	3	3	3	4	4	1	2	4	3	3	4	4	1	3	4	4	
L51	4	3	2	4	2	3	3	3	4	3	3	3	3	1	2	3	2	4	1	3	...	2	3	2	3	2	3	3	3	4	3	3	3	3	3	...	2	3	3	3	4	3	3	3	4	3	2	4	3	4	3	3	
L52	6	3	6	4	2	3	4	4	6	6	4	3	3	5	4	5	4	2	3	2	...	6	4	3	3	3	4	6	3	3	3	6	4	4	6	...	3	4	3	2	4	3	2	2	6	6	4	2	4	4	3	3	
L53	4	2	4	4	2	2	4	5	6	6	6	4	3	5	4	5	4	4	3	2	...	3	5	3	5	6	2	6	5	4	2	4	4	3	3	...	3	5	3	5	4	5	6	2	6	6	4	2	3	4	3	2	
L54	4	2	6	4	2	2	5	3	6	6	6	4	3	5	6	5	6	3	3	2	...	6	2	6	3	4	4	6	4	6	3	3	4	2	4	...	6	3	2	3	6	5	4	3	4	6	6	6	4	4	4	6	
L55	4	2	6	4	2	2	5	3	4	4	6	4	3	2	6	5	6	2	3	2	...	5	4	3	5	4	2	4	2	2	4	6	2	6	2	...	2	2	2	2	6	2	2	2	4	2	6	3	6	2	3	3	
L56	4	2	3	3	2	2	4	3	4	4	3	4	3	2	5	5	5	5	3	2	...	3	5	4	3	4	3	3	5	4	3	4	2	4	3	...	4	2	3	2	3	5	4	2	4	3	3	5	3	2	4	4	
L57	4	2	3	4	2	2	3	5	4	4	4	4	3	2	5	5	5	3	1	2	...	1	2	4	5	3	5	4	5	2	2	3	4	3	2	...	4	2	5	2	4	3	4	2	3	3	5	2	4	2	3	5	
L58	6	4	2	2	2	2	6	6	4	4	6	4	3	1	5	5	5	1	3	2	...	6	3	4	6	4	4	6	1	2	6	6	4	2	4	...	6	2	6	4	6	1	2	3	2	2	2	2	2	3	3	6	6

Step 3: Aggregation of decision makers' opinion

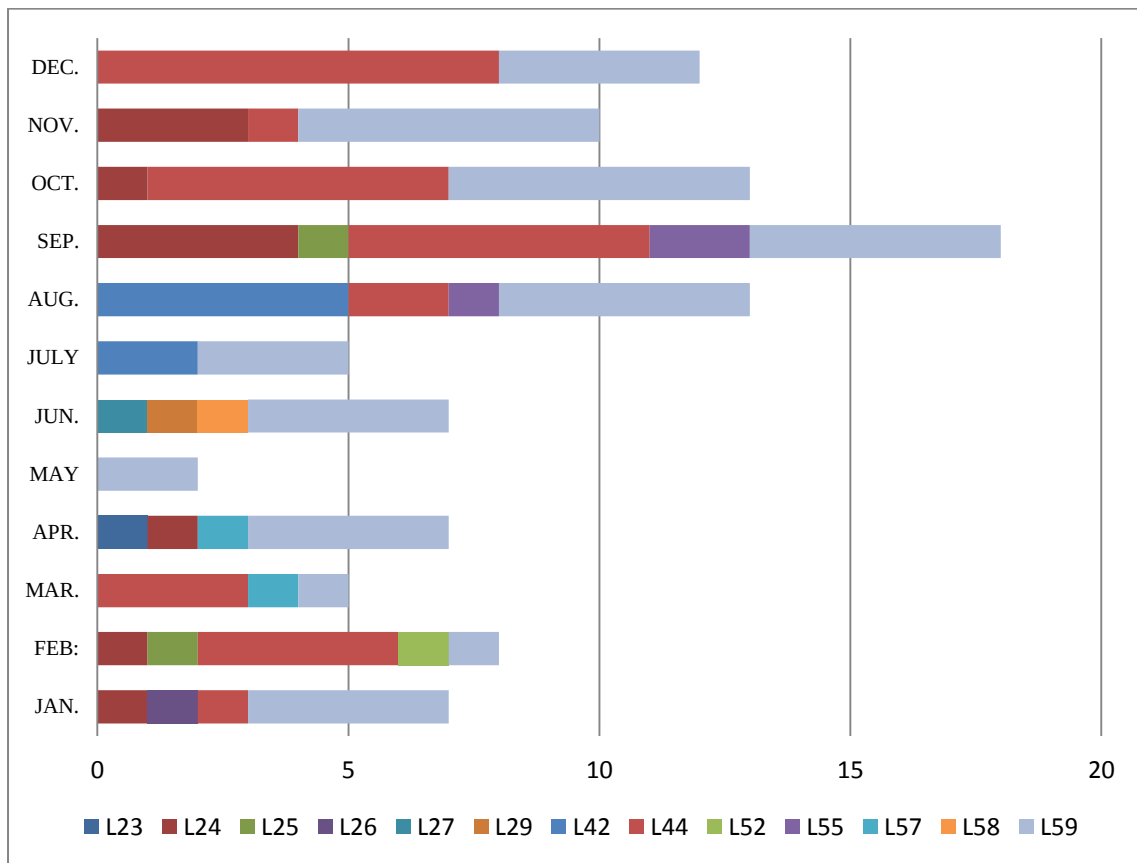
Collected answers are in the form of linguistic scale codes. For that reason, initially, all the collected answers are transformed to the scores via using the mentioned scales. After that IIFWA operator is used to aggregate the decision makers' opinions for severity and preventability attributes. Final are presented in Appendix 3. In this study, decision makers' are thought to be in the same level thus they are not weighted however it is possible to determine different weights to decision makers' based on their experiences and job title in further studies

Step 4: Calculation of final index scores with considering similarity

In this step, RPN is calculated including the frequency/occurrence score. In the determination of the frequency/occurrence, number of reported events in 2017 in the selected private hospital, are used. Distribution of errors in the observation period is presented with Figure 3.3. through Figure 3.6. presenting laboratory, medication, general/surgical and patient based errors respectively. Details of the reported errors are presented in Appendix 4.

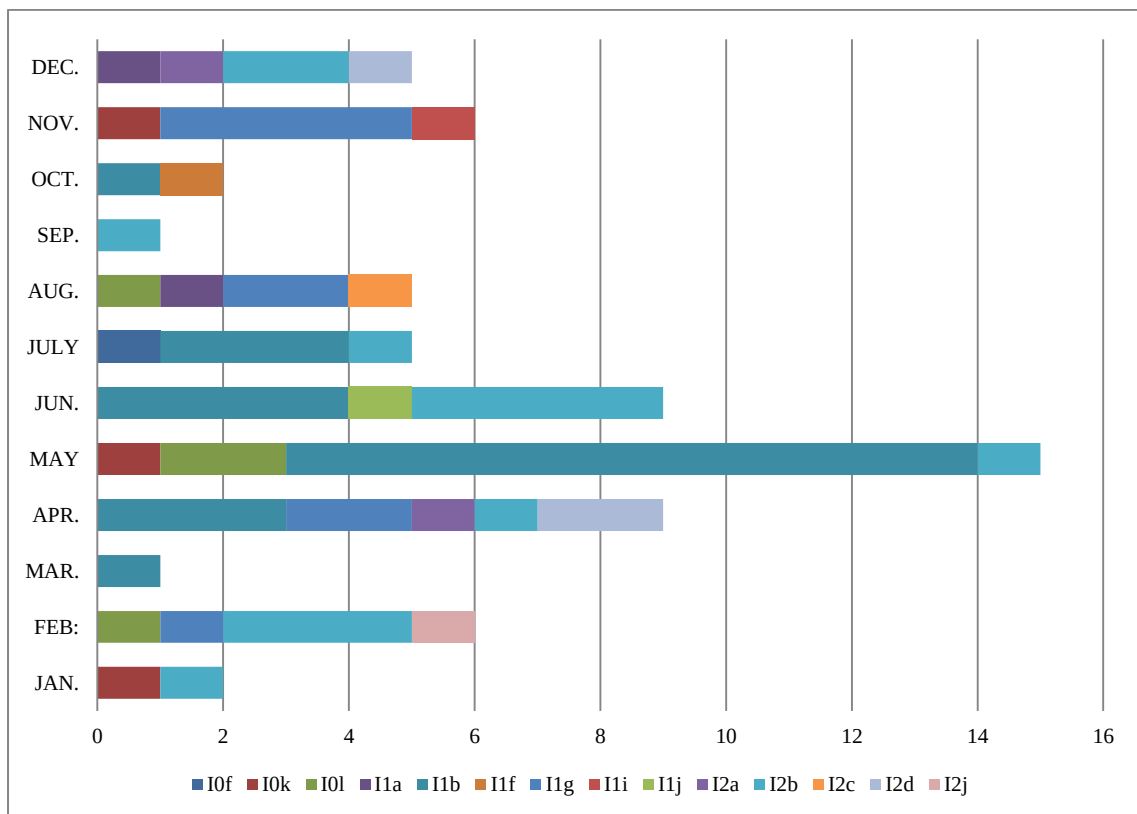


(a)

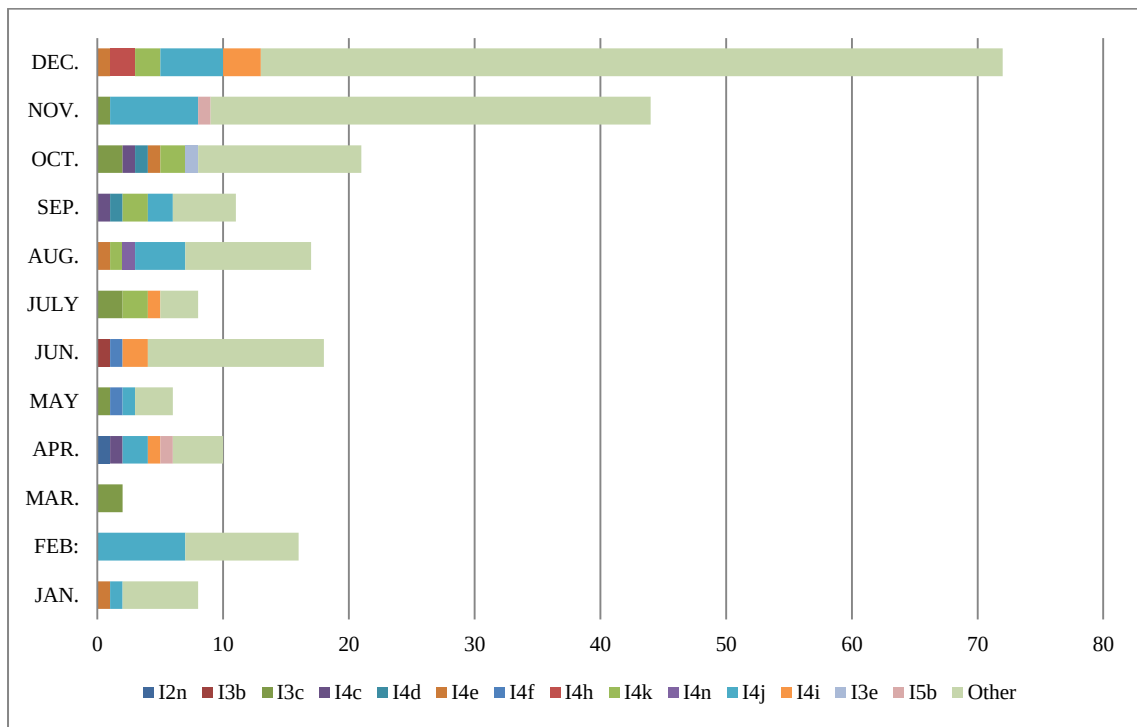


(b)

Figure 3.3. Number of occurred and reported laboratory errors in 2017



(a)



(b)

Figure 3.4. Number of occurred and reported medication errors in 2017

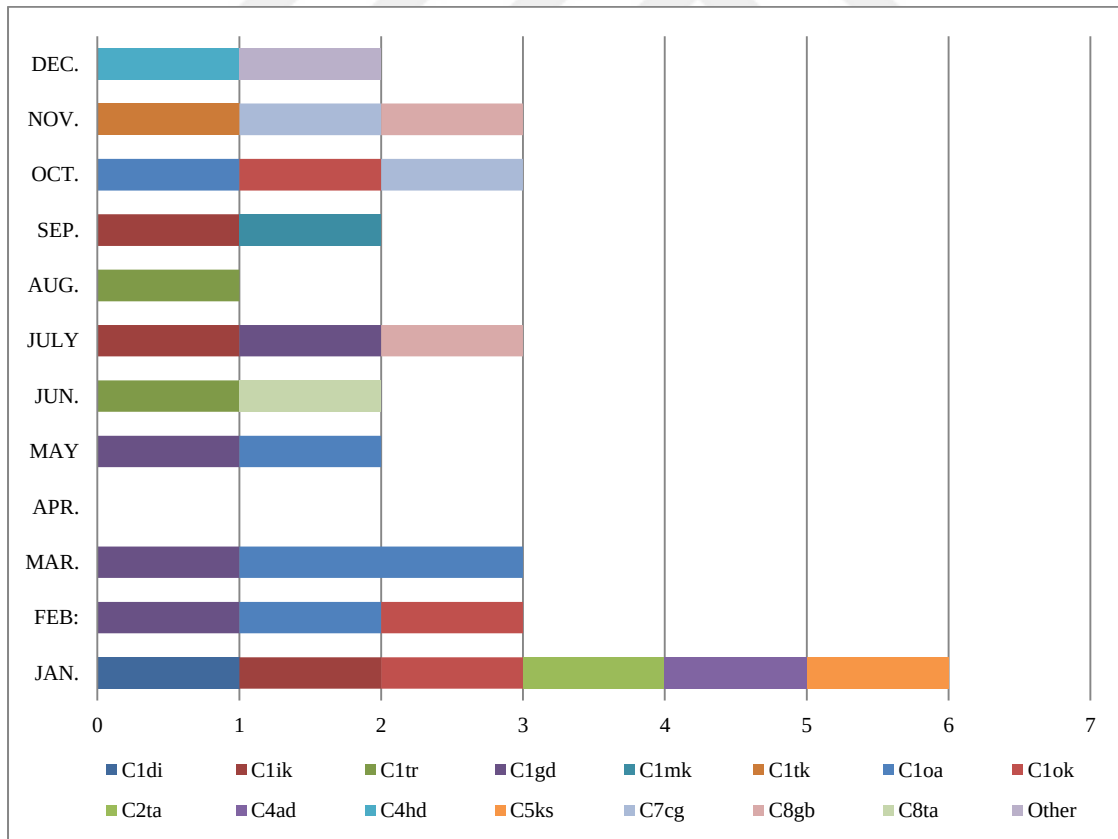
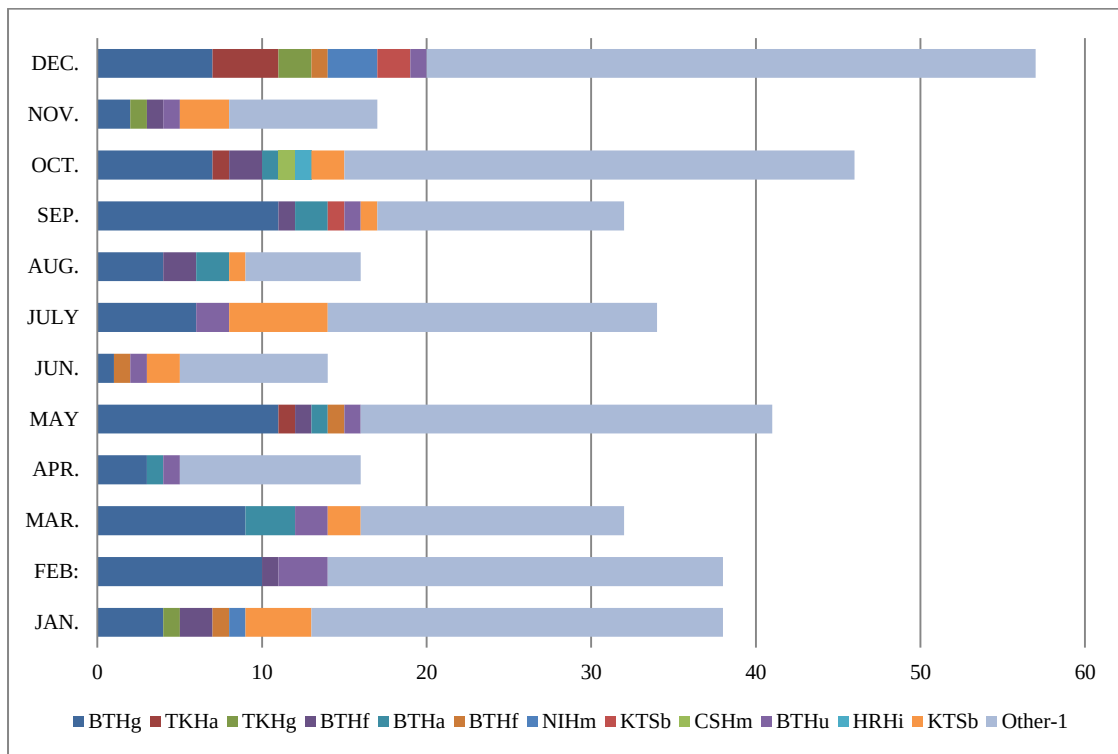
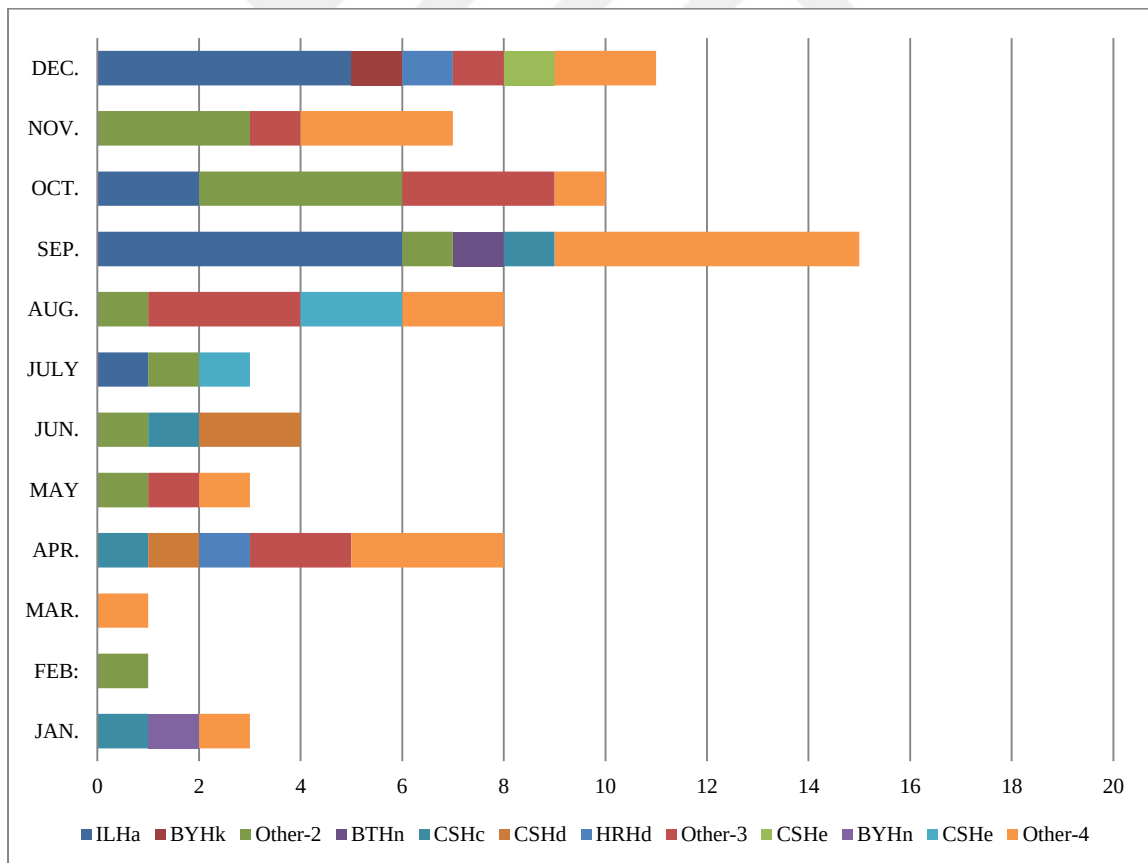


Figure 3.5. Number of occurred and reported general/surgical errors in 2017



(a)



(b)

Figure 3.6. Number of occurred and reported patient related errors in 2017

After frequency values are normalized, RPN score for each is found and results are presented in Appendix 5.

In determination of the final prioritization, similarity calculations are used. In calculations, current state is compared with the ideal case which refers to score that is provided by “rare” evaluation for frequency/occurrence. Thus, an index value for each error is achieved for first and second 6 month period (observations periods). A sample representing the laboratory errors is presented in the Table 3.13 referring the first 6 month period. High index scores means that the related error is close to the ideal case in other terms these errors are rarely seen.

Table 3.13. Index scores for laboratory errors for the first 6 month

Code	RPN				Ideal Case				Index Score
	(μ^L)	(μ^U)	(v^L)	(v^U)	(μ^L)	(μ^U)	(v^L)	(v^U)	
L01	0,3866	0,5425	0,2589	0,4575	0,0000	0,4471	0,3253	0,5529	0,7730
L02	0,4731	0,6097	0,2275	0,3903	0,0000	0,4487	0,3224	0,5513	0,6966
L03	0,0000	0,4573	0,3086	0,5427	0,0000	0,4573	0,3086	0,5427	1,0000
L04	0,3841	0,5386	0,2626	0,4614	0,0000	0,4439	0,3287	0,5561	0,7742
L05	0,3799	0,5347	0,2655	0,4653	0,0000	0,4407	0,3313	0,5593	0,7759
L06	0,0000	0,4570	0,3096	0,5430	0,0000	0,4570	0,3096	0,5430	1,0000
L07	0,4548	0,5971	0,2037	0,4029	0,0000	0,4624	0,3015	0,5376	0,7195
L08	0,3944	0,5471	0,2521	0,4529	0,0000	0,4509	0,3191	0,5491	0,7701
L09	0,0000	0,4379	0,3355	0,5621	0,0000	0,4379	0,3355	0,5621	1,0000
L10	0,4147	0,5582	0,2508	0,4418	0,0000	0,4323	0,3429	0,5677	0,7361
L11	0,0000	0,4383	0,3360	0,5617	0,0000	0,4383	0,3360	0,5617	1,0000
L12	0,0000	0,4437	0,3288	0,5563	0,0000	0,4437	0,3288	0,5563	1,0000
L13	0,3935	0,5466	0,2520	0,4534	0,0000	0,4504	0,3190	0,5496	0,7705
L14	0,0000	0,4382	0,3357	0,5618	0,0000	0,4382	0,3357	0,5618	1,0000
L15	0,4493	0,5897	0,2126	0,4103	0,0000	0,4567	0,3094	0,5433	0,7219
L16	0,0000	0,4529	0,3155	0,5471	0,0000	0,4529	0,3155	0,5471	1,0000
L17	0,0000	0,4506	0,3178	0,5494	0,0000	0,4506	0,3178	0,5494	1,0000
L18	0,0000	0,4462	0,3234	0,5538	0,0000	0,4462	0,3234	0,5538	1,0000
L19	0,0000	0,4502	0,3178	0,5498	0,0000	0,4502	0,3178	0,5498	1,0000
L20	0,0000	0,4551	0,3116	0,5449	0,0000	0,4551	0,3116	0,5449	1,0000
L21	0,3912	0,5443	0,2545	0,4557	0,0000	0,4486	0,3213	0,5514	0,7714
L22	0,0000	0,4445	0,3277	0,5555	0,0000	0,4445	0,3277	0,5555	1,0000
L23	0,3811	0,5346	0,2670	0,4654	0,0000	0,4406	0,3327	0,5594	0,7754
L24	0,3876	0,5400	0,2600	0,4600	0,0000	0,4450	0,3263	0,5550	0,7729
L25	0,4033	0,5576	0,2394	0,4424	0,0000	0,4596	0,3076	0,5404	0,7665
L26	0,4109	0,5658	0,2276	0,4342	0,0000	0,4663	0,2968	0,5337	0,7635
L27	0,3952	0,5478	0,2501	0,4522	0,0000	0,4515	0,3173	0,5485	0,7699
L28	0,0000	0,4463	0,3249	0,5537	0,0000	0,4463	0,3249	0,5537	1,0000
L29	0,3977	0,5514	0,2462	0,4486	0,0000	0,4544	0,3138	0,5456	0,7688

Table 3.13. (continued)

L30	0,0000	0,4521	0,3168	0,5479	0,0000	0,4521	0,3168	0,5479	1,0000
L31	0,0000	0,4451	0,3252	0,5549	0,0000	0,4451	0,3252	0,5549	1,0000
L32	0,0000	0,4542	0,3136	0,5458	0,0000	0,4542	0,3136	0,5458	1,0000
L33	0,0000	0,4529	0,3156	0,5471	0,0000	0,4529	0,3156	0,5471	1,0000
L34	0,0000	0,4474	0,3231	0,5526	0,0000	0,4474	0,3231	0,5526	1,0000
L35	0,0000	0,4558	0,3120	0,5442	0,0000	0,4558	0,3120	0,5442	1,0000
L36	0,0000	0,4548	0,3130	0,5452	0,0000	0,4548	0,3130	0,5452	1,0000
L37	0,0000	0,4530	0,3157	0,5470	0,0000	0,4530	0,3157	0,5470	1,0000
L38	0,0000	0,4417	0,3307	0,5583	0,0000	0,4417	0,3307	0,5583	1,0000
L39	0,0000	0,4515	0,3173	0,5485	0,0000	0,4515	0,3173	0,5485	1,0000
L40	0,0000	0,4573	0,3107	0,5427	0,0000	0,4573	0,3107	0,5427	1,0000
L41	0,0000	0,4506	0,3191	0,5494	0,0000	0,4506	0,3191	0,5494	1,0000
L42	0,0000	0,4514	0,3175	0,5486	0,0000	0,4514	0,3175	0,5486	1,0000
L43	0,0000	0,4505	0,3193	0,5495	0,0000	0,4505	0,3193	0,5495	1,0000
L44	0,4348	0,5761	0,2297	0,4239	0,0000	0,4461	0,3244	0,5539	0,7278
L45	0,0000	0,4588	0,3083	0,5412	0,0000	0,4588	0,3083	0,5412	1,0000
L46	0,0000	0,4524	0,3161	0,5476	0,0000	0,4524	0,3161	0,5476	1,0000
L47	0,0000	0,4604	0,3055	0,5396	0,0000	0,4604	0,3055	0,5396	1,0000
L48	0,0000	0,4549	0,3130	0,5451	0,0000	0,4549	0,3130	0,5451	1,0000
L49	0,0000	0,4451	0,3258	0,5549	0,0000	0,4451	0,3258	0,5549	1,0000
L50	0,0000	0,4470	0,3232	0,5530	0,0000	0,4470	0,3232	0,5530	1,0000
L51	0,0000	0,4487	0,3208	0,5513	0,0000	0,4487	0,3208	0,5513	1,0000
L52	0,4059	0,5596	0,2350	0,4404	0,0000	0,4612	0,3036	0,5388	0,7656
L53	0,0000	0,4572	0,3086	0,5428	0,0000	0,4572	0,3086	0,5428	1,0000
L54	0,0000	0,4696	0,2933	0,5304	0,0000	0,4696	0,2933	0,5304	1,0000
L55	0,0000	0,4721	0,2898	0,5279	0,0000	0,4721	0,2898	0,5279	1,0000
L56	0,0000	0,4601	0,3065	0,5399	0,0000	0,4601	0,3065	0,5399	1,0000
L57	0,4038	0,5563	0,2403	0,4437	0,0000	0,4584	0,3083	0,5416	0,7664
L58	0,4187	0,5747	0,2164	0,4253	0,0000	0,4737	0,2866	0,5263	0,7604

3.3.3. Calculation of importance values

In the proposed model, if the error is occurred in the observation period, index scores are accepted to create a ranking. However, in this study an importance value for each error is also calculated to see the ranking of the errors regardless of the frequency. The underlying reason is because of the unreliable structure of the reporting system. While examination of the report published by Ministry of Health, Turkey in 2016, %93,82 (69.782) of reported events constitute laboratory related errors. The underlying reason for this conclusion is directly related the reporting culture. In other words, error reporting and follow-up structure is considered as a basic part of the laboratory systems so this situation explains the encountered results. For that reason, errors are considered as if they are not occurred before and importance value for each of them is calculated

and a different ranking is also established. Weights of attributes are used to calculate a new RPN for each error based. In the new RPN calculations aggregated opinions of decision makers' for severity and preventability are used. Initially these calculated scores are used ranking the errors without considering the frequency/occurrence.

In Table 3.14. sample of errors related with patient sentered error types are listed based on their calculated importance values. All values are listed in Appendix 6 in a descending order.

Table 3.14. Importance scores for patient related errors

Error Code	Importance Score	Error Code	Importance Score	Error Code	Importance Score
BYHa	0,6575	TKHd	0,6447	HRHe	0,6567
BYHb	0,6747	TKHe	0,6369	HRHf	0,6377
BYHc	0,7019	TKHf	0,6451	HRHg	0,6478
BYHd	0,6850	TKHg	0,6681	HRHh	0,6376
BYHe	0,6454	ILHa	0,6337	HRHi	0,6239
BYHf	0,6551	ILHb	0,6535	HRHj	0,6494
BYHg	0,6169	ILHc	0,6198	HRHk	0,6153
BYHh	0,6486	BTHa	0,6642	HTHl	0,6209
BYHi	0,6704	BTHb	0,6699	HTHm	0,6198
BYHj	0,6980	BTHc	0,6466	HTHn	0,6239
BYHk	0,6895	BTHd	0,6634	KTSa	0,6928
BYHl	0,6614	BTHe	0,6733	KTSb	0,6341
BYHm	0,6617	BTHf	0,6648	KTSc	0,6756
BYHn	0,6808	BTHg	0,6671	KTSd	0,6748
BYHo	0,6346	BTHh	0,6950	KTSe	0,6379
BYHp	0,6697	BTHi	0,6466	KTSf	0,6582
CSHa	0,6503	BTHj	0,6564	KTSg	0,6359
CSHb	0,6603	BTHk	0,6521	NIHa	0,6539
CSHc	0,6820	BTHl	0,6779	NIHb	0,6794
CSHd	0,6658	BTHm	0,5947	NIHc	0,6691
CSHe	0,6612	BTHn	0,6578	NIHd	0,6698
CSHf	0,6774	BTHo	0,6832	NIHe	0,6569
CSHg	0,6008	BTHp	0,6209	NIHf	0,6940
CSHh	0,6721	BTHq	0,6468	NIHg	0,6499
CSHi	0,6136	BTHr	0,6766	NIHh	0,6563
CSHj	0,6534	BTHs	0,6674	NIHi	0,6648
CSHk	0,6210	BTHt	0,6633	NIHj	0,6639
CSHl	0,6414	BTHu	0,6641	NIHk	0,6597
CSHm	0,6198	BTHv	0,6633	NIHl	0,6698
CSHn	0,6950	HRHa	0,6583	NIHm	0,6709
TKHa	0,6928	HRHb	0,6580	NIHn	0,6586
TKHb	0,6886	HRHc	0,6950		
TKHc	0,6733	HRHd	0,6538		

4. RESULTS AND DISCUSSIONS

4.1. Analysis of Medical Errors in Selected Health Institution

Management of patient safety is required a comprehensive model therefore it is planned to generate an index system in which all medical errors are evaluated in terms of severity, preventability and occurrence/frequency criteria. Health institutions can be evaluated based on this index system since the occurrence/frequency of the error is only related with the evaluated health institution thus each error will have a unique score. After a unique score for each error is determined for the evaluated health institution, these scores are used to create index values. It is possible to create an index value in the level of each error, each department or each health institution. Moreover, these values can also be used to create a prioritization for the improvements in health institution and provide a continuous development cycle.

4.1.1. Prioritization of medical errors based on similarity values

According to the calculated index scores, it is possible to create a prioritization for the related errors. In Appendix 6, all values for each error are presented along with the ranking based on the number of reported issues. On the other hand, a sample is given in Table 4.1. presenting the first and the second 6 month observation period for surgical errors.

In the Table 4.1, score “1” represents the “possible highest value” that refers to 100% similarity to the ideal case. In other terms, hospital performs ideally in the related error types. For that reason to reach a ranking, errors should be ranked in an increasing order of index score.

Table 4.1. First and the second 6 month observation period for surgical errors

Error Code	1st 6 Month Index Score	2nd 6 Month Index Score	Error Code	1st 6 Month Index Score	2nd 6 Month Index Score
C1di	0,7615	1,0000	C4ad	0,7603	1,0000
C1ik	0,7614	0,7614	C4kk	1,0000	1,0000
C1ac	1,0000	1,0000	C4gc	1,0000	1,0000
C1tr	0,7653	0,7653	C4hd	1,0000	0,7645
C1gd	0,7678	0,7678	C5kd	1,0000	1,0000
C1oi	1,0000	1,0000	C5et	1,0000	1,0000
C1mk	1,0000	0,7622	C5kc	1,0000	1,0000
C1tk	1,0000	0,7710	C5ka	1,0000	1,0000
C1oa	0,7751	0,7751	C5sk	1,0000	1,0000
C1ok	0,7739	0,7739	C5cp	1,0000	1,0000
C2kd	1,0000	1,0000	C5ks	0,7650	1,0000
C2te	1,0000	1,0000	C5ko	1,0000	1,0000
C2ta	0,7671	1,0000	C5vp	1,0000	1,0000
C2ti	1,0000	1,0000	C6ku	1,0000	1,0000
C3at	1,0000	1,0000	C6pf	1,0000	1,0000
C3ak	1,0000	1,0000	C7gi	1,0000	1,0000
C3ck	1,0000	1,0000	C7ta	1,0000	1,0000
C3gk	1,0000	1,0000	C7pe	1,0000	1,0000
C3pk	1,0000	1,0000	C7cg	1,0000	0,7673
C3sn	1,0000	1,0000	C7ag	1,0000	1,0000
C3tg	1,0000	1,0000	C7gy	1,0000	1,0000
C4kd	1,0000	1,0000	C8gb	1,0000	0,7706
C4ok	1,0000	1,0000	C8kd	1,0000	1,0000
C4ik	1,0000	1,0000	C8ta	0,7671	1,0000
C4po	1,0000	1,0000	C8ts	1,0000	1,0000

Current performance of the selected health institution can be examined in each medical error group separately as follows. For the 1st 6 months observation period;

- Laboratory Errors:

Analyses showed that, selected hospital performed ideally (have an index score of 1) in 42 errors among 61 errors. This results a 68% success performance. For the rest, index scores are presented in Table 4.2 in an increasing order.

Table 4.2. Final index scores for laboratory errors for the 1st 6 months

Code	Index Score	Code	Index Score
POL59	0,69238	PRL29	0,76878
PRL02	0,69664	PRL27	0,76985
PRL07	0,71951	PRL08	0,77013
PRL15	0,72191	PRL13	0,77051
ANL44	0,72782	PRL21	0,77142
PRL10	0,73614	PRL24	0,77289
POL58	0,76044	PRL01	0,77303
PRL26	0,76354	PRL04	0,77416
ANL52	0,76558	PRL23	0,77545
POL57	0,76640	PRL05	0,77594
PRL25	0,76646		

In Table 4.2. POL59 has the lowest score means health institution have the lowest performance in this medical error. POL59 is not defined in the medical error list of Ministry of Health, Turkey. This is a special error code developed by health institution representing the other category of laboratory errors. Content of this error type is not shared by the health institution since it is a classified information however these types of error generally consists of issues that are related with the errors caused by health employee. Number of reported errors in this category is 16. The second error which has the second lowest performance is PRL02- “Missed/wrong information in test request”. Although number of reports for this error is 88, it is listed in the second order since its preventability score is higher than the POL59. Another point that should be considered is the PRL05 error type. This error has the highest index score which means that health institution have a good performance related to this error although it occurs in the observation period. However the interesting point is

number of reported events of PRL05 which is 4 and there are many errors that are occurred less than PRL05 such as PRL23, PRL26 and etc. As it is seen from the Table 4.2 these errors have worse performance than PRL05. The underlying reason of this situation is that the index score considers the preventability and severity values at the same time. These situations enhance the importance of study.

- Medication Errors:

According to the analyses, selected hospital performed ideally (have an index score of 1) in 54 error type among 73 errors. This results a 73% success performance. For the rest, index scores are presented in Table 4.3 in an increasing order.

Table 4.3. Final index scores for medication errors for the 1st 6 months

Code	Index Score	Code	Index Score
Other	0,69238	I0l	0,76615
I4j	0,71344	I2n	0,76699
I2b	0,71992	I1g	0,76759
I1b	0,72219	I3c	0,76830
I4e	0,75476	I2d	0,77223
I4c	0,75478	I2j	0,77223
I4f	0,76015	I1j	0,77296
I4i	0,76540	I2a	0,77351
I3b	0,76555	I0k	0,77740
I5b	0,76588		

“Other” category of errors has the lowest score means that health institution have the lowest performance in this medical error type. This is a special error code developed by health institution representing the other category of medication errors. Content of this error type is not shared by the health institution since it is a classified information however these types of error generally consists of issues that are related with the errors caused by health employee. Number of reported errors in this category is 36. One of the important point to be considered in this list is I0k-“Loss of drugs” and I0l-“Expired drugs”. Although reported number of events is higher than I0l; I0k is listed in the first place. The underlying reason is their preventability evaluations.

Preventability of I0k is evaluated as easier than the I01 thus, the index score increased.

- General/Surgical Errors:

Selected hospital performed ideally (have an index score of 1) in 40 error type among 50 errors. This results a %80 success performance. For the rest, index scores are presented in Table 4.4 in an increasing order.

Table 4.4. Final index scores for general/surgical errors for the 1st 6 months

Code	Index Score	Code	Index Score
C4ad	0,76028	C2ta	0,76714
C1ik	0,76143	C8ta	0,76714
C1di	0,76153	C1gd	0,76782
C5ks	0,76495	C1ok	0,77390
C1tr	0,76531	C1oa	0,77513

It is clearly seen from the Table 4.4. that, index score of each error is close to each other. The underlying reason is that errors in the general/surgical errors are generally having high severity evaluations. For that reason, frequency was the main determining factor of the ranking.

- Patient Related Errors:

In this category of medicals, selected hospital has a 75% success performance. The underlying reason for that hospital performed ideally (have an index score of 1) in 34 error type among 45 errors. For the rest, index scores are presented in Table 4.5 in an increasing order.

Table 4.5. Final index scores for patient related errors for the 1st 6 months

Code	Index Score	Code	Index Score
C09-22	0,65869	CSHc	0,75999
C09-5	0,69238	BYHn	0,76049
BTHg	0,71674	NIHm	0,76187
BTHu	0,71721	TKHg	0,76266
BTHa	0,71755	BTHf	0,76328
KTSb	0,72440	BTHf	0,76328
C09-9	0,74197	CSHd	0,76331
C09-7	0,74197	HRHd	0,76536
TKHa	0,75864		

Table 4.5. presented that, index score of C09-22 and C09-5 is the lowest score. These errors are represents the special codes which are determined by the health instution. In the selected health instution patient realted error list of Ministy of Health, Turkey is not used. Instead of that, health instution is determined new categories under the general/surgical error types with code of C09 such as;

- Treatment and Care Process Errors,
- Environmental Errors,
- Judicial Events,
- Errors related with Medical Equipment,
- Errors related with Medical Material.

Although errors categories are different, errors that are listed under these groups are same with the error list of Ministy of Health. For that reason, initially each error is matched with its related code in the list of Ministy of Health then analyses are completed. However, there some categories refer to “other” type of errors as well such as C09-22, C09-5, etc.

For the 2nd 6 months observation period analyses are as follows.

- Laboratory Errors:

Selected hospital performed ideally (have an index score of 1) in 45 error type among 61 errors. This results a 74% success performance. For the rest, index scores are presented in Table 4.6 in an increasing order.

Table 4.6. Final index scores for laboratory errors for the 2nd 6 months

Code	Index Score	Code	Index Score
POL59	0,69238	PRL24	0,72816
PRL07	0,71951	PRL10	0,73614
PRL15	0,72191	POL55	0,76056
PRL16	0,72372	PRL25	0,76646
ANL42	0,72520	PRL06	0,76794
PRL13	0,72541	PRL18	0,77148
PRL21	0,72644	PRL01	0,77303
PRL02	0,72688	PRL04	0,77416
ANL44	0,72782	PRL05	0,77594

It can be easily tracked from the Table 4.6. that, POL59 has the lowest score means that health institution have the lowest performance in this medical error. The second error which has the second lowest performance is PRL07-“Incorrect sample identification”. Although number of reports for this error is 11, it is listed in the second order since its preventability score is too low. As it can be tracked from the Table 4.6. again PRL05 error type has the highest index score. However the important point is the location of PRL15 is not changed over observation periods and showed a lower performance among others. In this regard, it is not wrong to say that this error type is a critical element and should be considered as a priority. Therefore, core reasons can be analyzed and the occurrence would be eliminated.

- Medication Errors:

Results demonstrated that selected hospital performed ideally (have an index score of 1) in 49 error type among 73 errors. This results a 67% success performance. For the rest, index scores are presented in Table 4.7 in an increasing order.

Table 4.7. Final index scores for medication errors for the 2nd 6 months

Code	Index Score	Code	Index Score
Other	0,65869	I5b	0,76588
I4j	0,71344	I0l	0,76615
I4k	0,72105	I3e	0,76676
I1g	0,72204	I1b	0,76770
I3c	0,72287	I1a	0,76920
I4e	0,75476	I2d	0,77223
I4c	0,75478	I1i	0,77296
I4d	0,75507	I2c	0,77313
I4n	0,76130	I2a	0,77351
I4h	0,76540	I1f	0,77408
I4i	0,76540	I0f	0,77597
I2b	0,76577	I0k	0,77740

In the second observation period “Other” has the lowest score means that health institution have the lowest performance in this medical error. One of the important point to be considered in this list is I4j is again in the same place thus this error can be considered as a critical element which should be examined in detail.

- General/Surgical Errors:

Examination of the analyses provided that, selected hospital performed ideally (have an index score of 1) in 40 error type among 50 errors. This results an 80% success performance. For the rest, index scores are presented in Table 4.8. in an increasing order.

Table 4.8. Final index scores for general/surgical errors for the 2nd 6 months

Code	Index Score	Code	Index Score
C1lk	0,76143	C1gd	0,76782
C1mk	0,76215	C8gb	0,77059
C4hd	0,76453	C1tk	0,77096
C1tr	0,76531	C1ok	0,77390
C7cg	0,76730	C1oa	0,77513

It is clearly seen from the Table 4.8. that, index score of each error is close to each other. The underlying reason is that errors in the general/surgical errors are generally having high severity evaluations. For that reason, frequency was the determining factor of the ranking.

- Patient Related Errors:

Among 45 errors, selected hospital performed ideally (have an index score of 1) in 28 error type. This results a 62% success performance. For the rest, index scores are presented in Table 4.9 in an increasing order.

Table 4.9. Final index scores for patient related errors for the 2nd 6 months

Code	Index Score	Code	Index Score
C09-22	0,65869	CSHc	0,75999
C09-9	0,69238	NIHm	0,76187
C09-7	0,69238	TKHg	0,76266
C09-5	0,69238	BTHf	0,76328
TKHa	0,71167	CSHe	0,76409
BTHg	0,71674	CSHe	0,76409
BTHf	0,71707	BTHn	0,76533
BTHu	0,71721	HRHd	0,76536
BTHa	0,71755	KTSb	0,76964
ILHa	0,72387	HRHi	0,77175
KTSb	0,72440	CSHm	0,77301
BYHk	0,75850		

It Table 4.9., index score of C09-22 and C09-9 are the lowest scores. These errors are represents the special codes which are determined by the health instution as it is mentione before.

In the current situation, reported number of events is the only dimension that is considered when prioritizing the errors. If the reported number of errors is high then the related error gains much more priority among others and improvements are planned base on this ranking. However, as it is mentioned before and clealry seen from the analyses, it is not suitable to evaluate risks based only on the frequency especially for healthcare institutions. When the severity and the preventability of the errors are evaluated, ranking is completely changes.

Errors shuold be examined according to their index scores. Since the lowest values represents the worst scenario, it is better to focus on the worst outcomes initially to achieve important imporvements. After all index scores are calculated, errors which have a index score of 1 (means 100% smilarity to ideal case) are eliminated. These errors will be considered again in the prioritization based on importance score part.

4.1.2. Prioritization of medical errors based on importance score

The main aim in calculating importance weights and making a classification based on these values is that taking precautions for errors in a systematic way. In other terms, the fact that an error has not occurred before, does not mean that related error will not occur later. For this reason, system should consider every dimension and preventive mechanisms should be taken into account if it is necessary. Thus, it is possible to evaluate the general position of the health institutions with a proactive view of point.

In ranking the results are calculated by accuracy function proposed by Garg (2016). In the accuracy calculations, different versions of the k_1 and k_2 are considered since it changes given importance to membership and non-membership hesitation degrees. Final results for each error are presented in Appendix however a sample which includes the top ten errors is also provided in Table 4.10. It is clearly seen form the table that except the final column basic ranking remains same. This situation proves that the model is good in dealing with hesitation. In table final score for importance weights are presented.

Table 4.10. Sample ranking of errors based on the importance values (preventability * severity)

	k ₁ =0 k ₂ =1		k ₁ =0,25 k ₂ =0,75		k ₁ =0,50 k ₂ =0,50		k ₁ =0,75 k ₂ =0,25		k ₁ =1 k ₂ =0	
Code	Score	R	Score	R	Score	R	Score	R	Score	R
Wrong dosage (high)	0,6352	1	0,6731	1	0,7110	1	0,7490	1	0,7869	1
Wrong patient	0,6349	2	0,6728	2	0,7108	2	0,7487	2	0,7866	2
Wrong drug	0,6336	3	0,6713	3	0,7091	3	0,7469	3	0,7847	3
Impaired drug application	0,6303	4	0,6674	4	0,7044	4	0,7415	4	0,7785	4
Patient fall/injured due to the escalator malfunction	0,6274	5	0,6646	5	0,7019	5	0,7391	6	0,7763	6
Do not check that the outlets are connected to uninterruptible power supply	0,6267	6	0,6643	6	0,7018	6	0,7394	5	0,7770	5
Injured patients due to the electric leakage	0,6242	7	0,6611	7	0,6980	7	0,7349	8	0,7718	9
Failure of cleaning of operation room and surgical table	0,6236	8	0,6608	8	0,6980	8	0,7352	7	0,7724	7
Not controlling the medical gas system	0,6235	9	0,6606	9	0,6978	9	0,7349	9	0,7720	8
Not evaluating the necessity of blood transfusion	0,6214	10	0,6586	10	0,6958	10	0,7330	10	0,7702	10

It is clearly seen that if the reporting mechanism is good and the number of reported events reflects the actual number of errors occurred in the health institutions, index scores that are generated by proposed model is create a proper inputs for improvement. On the other hand, even if the reporting mechanism is not organized very well, importance values that are also generated by the proposed model creates a proper inputs again.

4.2. Examination of the model: Turkey case

In Turkey, quality improvement studies are started in 2003 in the context of Health Transformation Program and then standardization programs for hospitals are developed and pilot studies with several trainings are planned. More recently, quality indicators for healthcare are determined within the scope of quality improvement studies. Additionally, a “Classification system for patient safety errors” has been created by determining the error codes with the safety reporting system and thus following up of errors are targeted.

Safety reporting system which is generated by Ministry of Health, Turkey, -is a platform that health institutions and professionals can report medical errors thus they can informed with common errors and precautions of these errors-, medical errors are classified into four main categories such as (i) laboratory, (ii) medication, (iii) general/ surgical and (iv) patient centered errors. In each category there are also several sub-categories based on the procedure of the related system.

In Table 4.11 and Table 4.12 aggregated values for the selected errors (mostly occurred error based on the safety reporting system) are presented. In this study, decision makers' are thought to be in the same level thus they are assumed to have equal weights. However in further studies decision makers' can be weighted based on their experiences and job title.

Table 4.11. Final aggregated scores for errors in terms of severity evaluations

Error Type	Code	Error Name	Membership Values (μ) (μ^L ; μ^U)	Non-Membership Values (v) (v^L ; v^U)
LABORATORY	L18	Clotted sample	(0,472 ; 0,572)	(0,277 ; 0,428)
	L17	Sample with hemolysis	(0,485 ; 0,585)	(0,264 ; 0,415)
	L16	Insufficient sample	(0,466 ; 0,570)	(0,281 ; 0,430)
	L05	Wrong record	(0,432 ; 0,550)	(0,303 ; 0,450)
	L01	Wrong test request	(0,415 ; 0,530)	(0,328 ; 0,470)
MEDICATION	I1g	Erroneous dosing	(0,537 ; 0,637)	(0,211 ; 0,363)
	I1a	Wrong drug demand	(0,505 ; 0,605)	(0,244 ; 0,395)
	I0a	Inappropriate temperature and humidity	(0,410 ; 0,528)	(0,331 ; 0,472)
	I2b	Preparation of wrong drug	(0,538 ; 0,643)	(0,202 ; 0,357)
	I3c	Transferring wrong drug from pharmacy	(0,486 ; 0,590)	(0,259 ; 0,410)
GENERAL / SURGICAL	di	Non-marking of operation area/side	(0,551 ; 0,651)	(0,197 ; 0,349)
	kd	Unverified Patient ID, location of operation and surgical procedure	(0,529 ; 0,630)	(0,219 ; 0,370)
	gd	Not confirming removal of make-up, prosthesis and valuable items	(0,483 ; 0,585)	(0,264 ; 0,415)
	tr	The operation area has not been shaved	(0,491 ; 0,595)	(0,254 ; 0,406)
	ts	Health worker does not accompany patient transfer	(0,482 ; 0,582)	(0,267 ; 0,418)
PATIENT RELATED	HRHc	Patient Falls	(0,596 ; 0,697)	(0,146 ; 0,303)
	TKHg	Incorrect report of patient basic information	(0,531 ; 0,631)	(0,217 ; 0,369)
	TKHa	Incorrect identification of patients	(0,582 ; 0,684)	(0,157 ; 0,316)

Table 4.12. Final aggregated scores for errors in terms of preventability evaluations

			Membership Values (μ)	Non-Membership Values (ν)
Error Type	Code	Error Name	($\mu^L ; \mu^U$)	($\nu^L ; \nu^U$)
LABORATORY	L18	Clotted sample	(0,553; 0,654)	(0,193 ; 0,346)
	L17	Sample with hemolysis	(0,555 ; 0,656)	(0,190 ; 0,344)
	L16	Insufficient sample	(0,586 ; 0,687)	(0,160 ; 0,313)
	L05	Wrong record	(0,559 ; 0,660)	(0,188 ; 0,340)
	L01	Wrong test request	(0,618 ; 0,718)	(0,130 ; 0,282)
MEDICATION	I1g	Erroneous dosing	(0,511 , 0,619)	(0,227 ; 0,382)
	I1a	Wrong drug demand	(0,533 ; 0,636)	(0,212 ; 0,364)
	I0a	Inapprropriate tempereture and humidity	(0,560 ; 0,700)	(0,147 ; 0,300)
	I2b	Preparation of wrong drug	(0,527 ; 0,631)	(0,217 ; 0,369)
	I3c	Transferring wrong drug from pharmacy	(0,566 ; 0,667)	(0,181 ; 0,333)
GENERAL / SURGICAL	di	Non-marking of operation area/side	(0,554 ; 0,658)	(0,183 ; 0,342)
	kd	Unverified Patient ID, location of operation and surgical procedure	(0,558 ; 0,663)	(0,180 ; 0,337)
	gd	Not confirming removal of make-up, prosthesis and valuable items	(0,576 ; 0,682)	(0,160 ; 0,318)
	tr	The operation area has not been shaved	(0,591 ; 0,696)	(0,146 ; 0,304)
	ts	Health worker does not accompany patient transfer	(0,572 ; 0,678)	(0,166 ; 0,322)
PATIENT RELATED	HRHc	Patient Falls	(0,543 ; 0,645)	(0,199 ; 0,356)
	TKHg	Incorrect report of patient basic information	(0,566; 0,671)	(0,175 ; 0,329)
	TKHa	Incorrect identification of patients	(0,547 ; 0,656)	(0,186 ; 0,344)

In this step, RPN is calculated including the frequency/occurrence score. In the determination of the frequency/occurrence scores, number of reported events in 2016 is used and then values are normalized. Finally, RPN is found via using equation 2 and results are presented in Table 4.13.

RPNs are also used to calculate overall index values. To determine the final prioritization similarity calculations which are given in equations 21 through 26 are used. In calculations, current state is compared with the ideal case. The ideal case refers to “rare” evaluation for frequency/occurrence. Thus, an index value for each error is

achieved and presented in the Table 9 as well. High index scores means that the related error is close to the ideal case in other terms these errors are rarely seen. For this reason errors are listed in the increasing order based on the index values.

Table 4.13. Ranking of errors with index score (preventability*severity*occurrence)

	RPN		Ideal Case		Similarity	
Code	$(\mu^L; \mu^U)$	$(v^L; v^U)$	$(\mu^L; \mu^U)$	$(v^L; v^U)$	Score	R
L18	(0,532 ; 0,657)	(0,179 ; 0,343)	(0 ; 0,446)	(0,323 ; 0,554)	0,638	2
L17	(0,538 ; 0,663)	(0,172 ; 0,337)	(0 ; 0,451)	(0,318 ; 0,549)	0,635	1
L16	(0,513 ; 0,642)	(0,193 ; 0,358)	(0 ; 0,453)	(0,315 ; 0,547)	0,662	5
L05	(0,516 ; 0,649)	(0,189 ; 0,351)	(0 ; 0,441)	(0,331 ; 0,559)	0,644	4
L01	(0,525 ; 0,658)	(0,181 ; 0,342)	(0 ; 0,447)	(0,325 ; 0,553)	0,640	3
I1g	(0,486 ; 0,620)	(0,213 ; 0,380)	(0 ; 0,457)	(0,310 ; 0,543)	0,691	11
I1a	(0,482 ; 0,614)	(0,221 ; 0,386)	(0 ; 0,452)	(0,317 ; 0,548)	0,693	14
I0a	(0,462 ; 0,601)	(0,237 ; 0,399)	(0 ; 0,443)	(0,331 ; 0,557)	0,701	15
I2b	(0,492 ; 0,627)	(0,206 ; 0,373)	(0 ; 0,461)	(0,304 ; 0,539)	0,689	10
I3c	(0,484 ; 0,618)	(0,217 ; 0,382)	(0 ; 0,455)	(0,313 ; 0,545)	0,692	13
di	(0,505 ; 0,639)	(0,193 ; 0,361)	(0 ; 0,470)	(0,292 ; 0,530)	0,684	8
kd	(0,498 ; 0,632)	(0,201 ; 0,368)	(0 ; 0,465)	(0,299 ; 0,535)	0,686	9
gd	(0,486 ; 0,620)	(0,213 ; 0,380)	(0 ; 0,456)	(0,310 ; 0,544)	0,692	12
tr	(0,455 ; 0,597)	(0,204 ; 0,403)	(0 ; 0,462)	(0,302 ; 0,538)	0,719	17
ts	(0,447 ; 0,587)	(0,216 ; 0,413)	(0 ; 0,455)	(0,312 ; 0,545)	0,723	18
HRHc	(0,517 ; 0,651)	(0,179 ; 0,349)	(0 ; 0,479)	(0,280 ; 0,521)	0,679	6
TKHg	(0,462 ; 0,604)	(0,198 ; 0,396)	(0 ; 0,468)	(0,297 ; 0,532)	0,716	16
TKHa	(0,513 ; 0,650)	(0,179 ; 0,350)	(0 ; 0,479)	(0,280 ; 0,521)	0,680	7

According to the calculated index scores, it is possible to create a prioritization for the related error. In Table 10, all values for each error are presented along with the ranking based on the number of reported issues.

Table 4.14. Comparison of rankings

Code	Ranking based on Index Score	Ranking based on reported number of events
L18	2	1
L17	1	2
L16	5	5
L05	4	4
L01	3	3
I1g	11	7
I1a	14	9
I0a	15	12
I2b	10	10
I3c	13	14
di	8	6
kd	9	11
gd	12	13
tr	17	17
ts	18	18
HRHc	6	8
TKHg	16	16
TKHa	7	15

In the current situation, reported number of events is the only dimension that is considered when prioritizing the errors. If the reported number of errors is high then the related error gains much more priority among others and improvements are planned base on this ranking. However, as it is mentioned before, it is not suitable to evaluate risks based only on the frequency especially for healthcare institutions. When the severity and the preventability of the errors are evaluated, ranking is completely changes.

In the proposed model, if the error is occurred in the observation period, index scores are accepted to create a ranking. However, in this study an importance value for each error is also calculated to see the ranking of the errors regardless of the frequency. The underlying reason is because of the unreliable structure of the reporting system. While examination of the report published by Ministry of Health, Turkey in 2016, %93,82 (69.782) of reported events constitute laboratory related errors. The underlying reason for this conclusion is directly related the reporting culture. In other words, error reporting and follow-up structure is considered as a basic part of the laboratory systems so this situation explains the encountered results. For that reason, errors are considered as if they are not occurred before and importance value for each of them is calculated and a different ranking is also established.

Weights of attributes are used to calculate a new RPN for each error based on the equation 2. In the new RPN calculations aggregated opinions of decision makers' for severity and preventability which are determined in step 2 are used. Initially these calculated scores are used ranking the errors without considering the frequency/occurrence. This analysis refers to the "classification of errors based on the importance values" in Figure 1 and presented in Table 4.15. In ranking the results are calculated by accuracy function proposed by Garg (2016) and given in equation 15. In the accuracy calculations, different versions of the k_1 and k_2 are considered since it changes given importance to membership and non-membership hesitation degrees. It is clearly seen from the table that excepts the final column basic ranking remains same. This situation proves that the model is good in dealing with hesitation.

Table 4.15. Ranking of errors based on the importance values (preventability*severity)

	$k_1=0$ $k_2=1$		$k_1=0,25$ $k_2=0,75$		$k_1=0,50$ $k_2=0,50$		$k_1=0,75$ $k_2=0,25$		$k_1=1$ $k_2=0$	
Code	Score	R	Score	R	Score	R	Score	R	Score	R
L18	0,559	15	0,591	15	0,623	15	0,655	15	0,687	15
L17	0,567	14	0,600	14	0,632	14	0,665	14	0,698	14
L16	0,570	12	0,603	12	0,636	12	0,669	12	0,702	12
L05	0,543	18	0,575	18	0,607	18	0,639	18	0,670	18
L01	0,555	16	0,587	16	0,620	16	0,652	16	0,684	16
I1g	0,576	9	0,610	9	0,644	9	0,678	9	0,711	9
I1a	0,569	13	0,601	13	0,634	13	0,667	13	0,700	13
I0a	0,546	17	0,578	17	0,610	17	0,641	17	0,673	17
I2b	0,585	7	0,619	7	0,654	7	0,688	7	0,723	7
I3c	0,573	11	0,606	11	0,640	11	0,673	11	0,706	11
di	0,603	3	0,639	3	0,674	3	0,710	3	0,745	3
kd	0,594	5	0,628	5	0,663	5	0,698	5	0,733	5
gd	0,576	8	0,610	8	0,644	8	0,678	8	0,712	8
tr	0,588	6	0,622	6	0,657	6	0,692	6	0,726	6
ts	0,573	10	0,607	10	0,640	10	0,674	10	0,707	10
HRHc	0,621	1	0,658	1	0,695	1	0,732	1	0,769	1
TKHg	0,598	4	0,633	4	0,668	4	0,703	4	0,738	4
TKHa	0,618	2	0,655	2	0,693	2	0,730	2	0,767	2

The main aim is that taking precautions for errors in a systematic way. In other terms, the fact that an error has not occurred before, does not mean that related error will not occur later. For this reason, system should consider every dimension and preventive mechanisms should be taken into account if it is necessary. Thus, it is possible to evaluate the general position of the health institutions with a proactive view of point. In the given example, index scores are taken into account as the final list for improvement stage. However in this study it is proven that a good reporting mechanism is an essential point initially.

It is clearly seen that if the reporting mechanism is good and the number of reported events reflects the actual number of errors occurred in the health institutions, index scores that are generated by proposed model is create a proper inputs for improvement. On the other hand, even if the reporting mechanism is not organized very well, importance values that are also generated by the proposed model creates a proper inputs again.

4.3. Examination of the model: International Case

Australian health system highlights the importance of safety and quality via managing clinical risk of health service organizations, measuring and reporting sentinel events and patient experiences. In this regard, several actions are developed and implemented and nationally consistent approach to improving the safety and quality of care is adopted (Australian Commission on Safety and Quality in Health Care, 2008; 2013; 2017; 2018; 2019) However, preventable adverse events are occurred although most health care leads to good outcomes in Australian health system (Harrison, et al., 2016).

Nowadays, global understanding of safety and quality issues improves, thus, the Australian Commission on Safety and Quality in Health Care and partners have continued to evolve Australia's approach (ACSQHC, 2019). Internationally, and within the Australian health system, as the number of patients continue the rise, the need to a system in which not only errors methodically reviewed but also prioritized to identify the most critical ones to used resources efficiently (Kaushal et al.,2001 ; Hirzt et al., 2002).

In the following part, proposed model for prioritizing of medical errors is applied to mostly seen medication related errors in New South Wales (NSW) public health system, Australia (Clinical ExcellenComission, 2019). In NSW, reporting medical

errors, which is defined as any unplanned event that threatened patient safety, is mandatory and health staff is responsible to report all the incidents, near misses and complaints via using by incident information management system(IIMS). According to the IIMS data provided by Clinical Excellence Commission (2019), medication related incidents were the second most commonly reported clinical incident in the second half of 2018 (2nd six month period-July-December). It is reported that over 99% of these medication related incidents are resulted little or no harm to patients however, it is still vital to determine preventive actions to decrease the frequency of the incidents.

In the current system, incidents are classified according to the Principal Incident Types and then categorized with severity assessment code (SAC) (SA Health Safety and Quality Unity, 2019). There are four SAC categories from 1 through 4 representing the risk levels from extreme risk to low risk respectively. SAC system provides valuable information and guides examination of the related incident thus preventive actions are planned however; only severity and the occurrence factors of the related incident are considered to obtain a score. On the other hand, risk management studies in the literature and occupational health and safety regulations are also emphasize the importance of the preventability/ detectability of the related error. According to the World Health Organization (Loeb and Chang, 2003), the ideal medication related error classification system should takes into consideration the dynamics of how medication errors may occur and addresses possible methods that can be used to prevent them.

In the analysis, five DMs evaluated the alternatives based on their experiences and beliefs. The underlying reason why a new evaluation is made is that the difference in the definition of errors. Most commonly reported medication related incidents in the 2018 according to the IIMS data are selected as the alternatives. Selected errors are listed based on their frequency in a descending order as follows;

- Administration (x_1)
- Prescribing problems (x_2)
- Dispensing problems (x_3)
- Narcotic/ controlled drug discrepancy (x_4)
- Storage/wastage/security (x_5)
- Delivery problems (x_6)
- Supply/ordering problems (x_7)
- Undesired drug effect during therapeutic use (x_8)

- Presentation (x_9)
- Other (x_{10})

According to determined attributes, DMs provide their linguistic evaluation values over the alternatives. Then, decision matrix for group, is created. According to the results, final list for prioritization is achieved. Based on the results, “Administration(x_1)” selected as the most important laboratory error among selected errors. The rest of the prioritization list is as follows;

- Narcotic/ controlled drug discrepancy (x_4)
- Other (x_{10})
- Prescribing problems (x_2)
- Dispensing problems (x_3)
- Presentation (x_9)
- Storage/wastage/security (x_5)
- Delivery problems (x_6)
- Undesired drug effect during therapeutic use (x_8)
- Supply/ordering problems (x_7)

In this study, proposed model is presented with a numerical example, which includes most frequent medication related errors in NSW public health system. According to the IIMS data, 63% of the reported all medication incidents in 2018 is categorized in SAC4, which is the lowest severity rating, and 32% of them is in SAC3 category. It is stated in the report that the reported incident scores in terms of SAC score are consistent with the previous years. Although there is consistency in terms of SAC scoring, there is a slight increase in certain error types when the frequency of the errors are analysed during 2014-2018 which is presented in Figure 4.1.

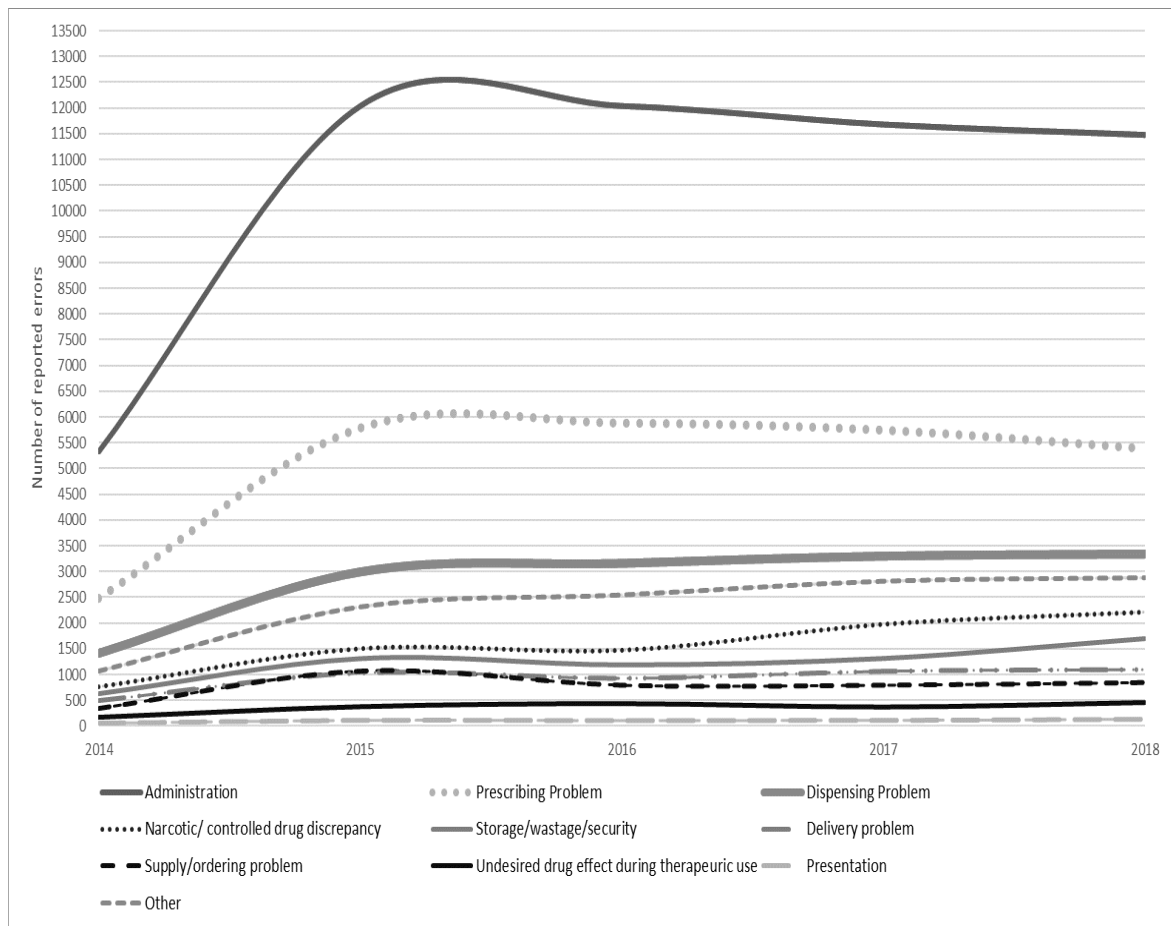
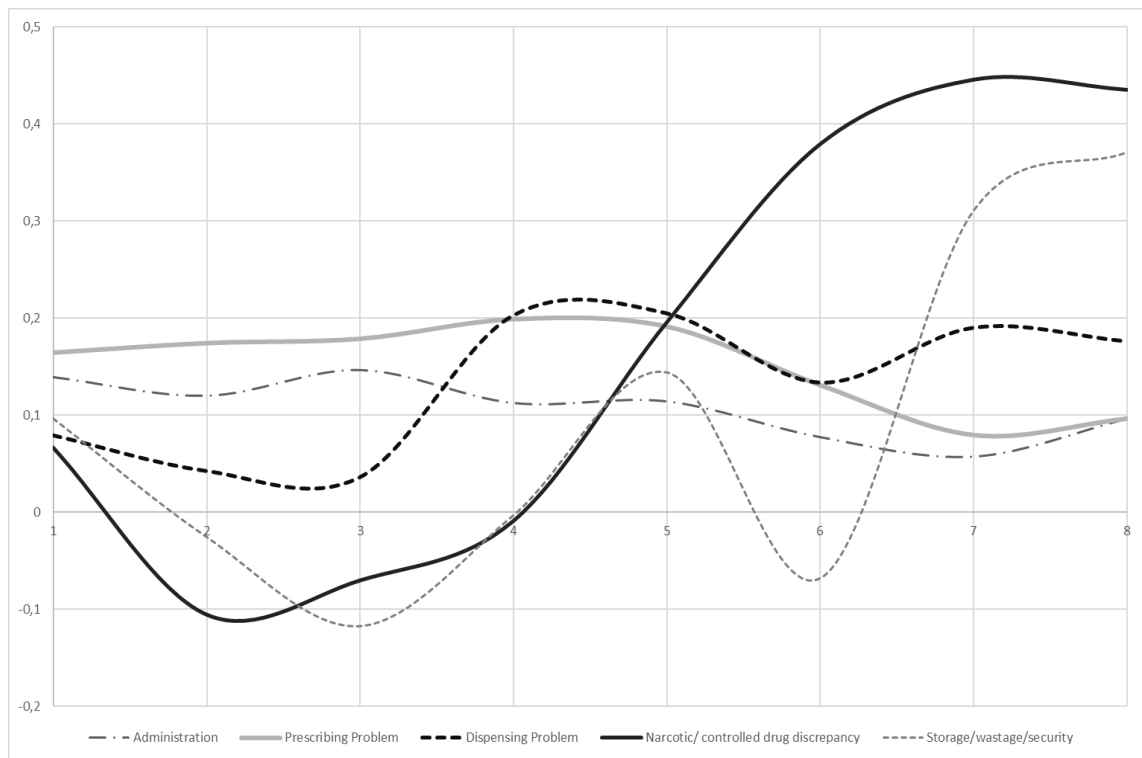
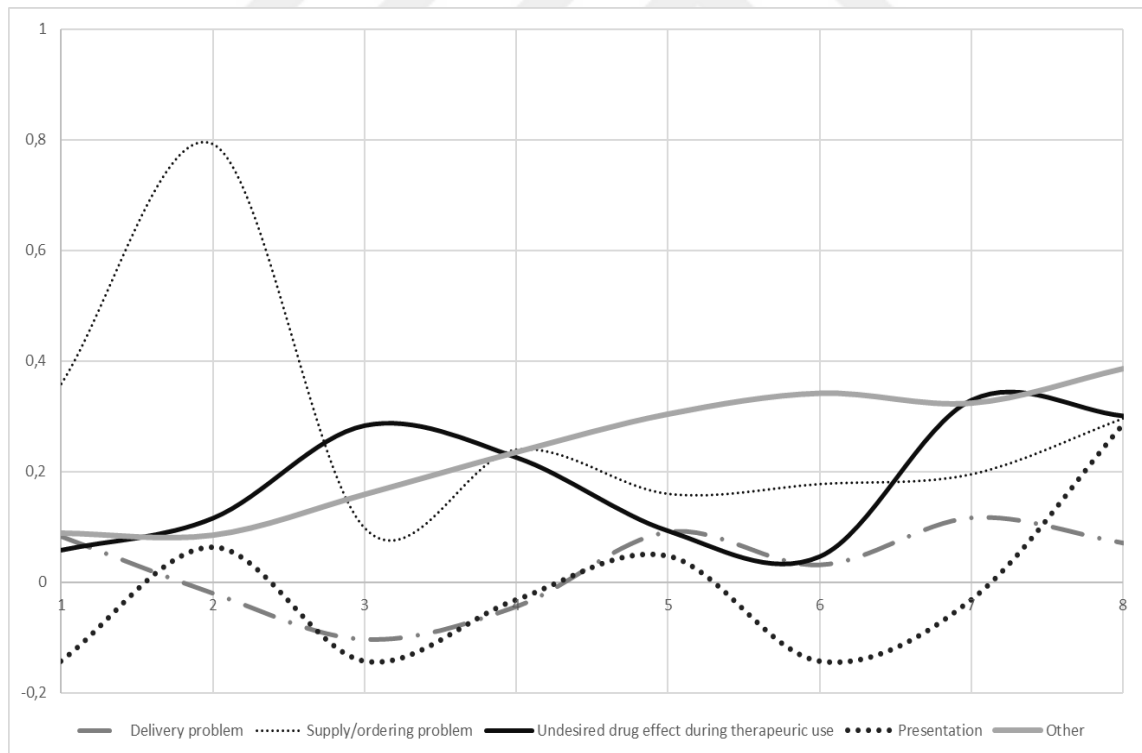


Figure 4.1. Number of reported errors during 2014-2018

It is clearly seen from the Figure 2 that reported errors especially in “Narcotic/ controlled drug discrepancy(x_4)”; “Storage/ wastage/ security(x_5)”; “Other(x_{10})” and Presentation (x_9) categories there is an increase in the number of reported errors. In this regard, to understand the changes better, all mostly reported medication related incidents in de 2014-2108 periods are examined in terms of their trend. In Figure 4.2. (a) and 4.2. (b) trends of the related errors are presented.



(a)



(b)

Figure 4.2. Trend of commonly reported medication errors during 2014-2018

Trend analysis of the errors is clearly revealed the changes among years and as it is seen from the Figure 4.2.(a) there is an radical increase in the reported number of errors in “Storage/ wastage/ security(x_5)”; and from the Figure 4.2. (b) in “Other(x_{10})” and Presentation (x_9) categories. Moreover, “Narcotic/ controlled drug discrepancy(x_4)” should be taken into consideration in detail as well, although there is a slight decrease in the last reporting period.

In the current system, SAC scoring provides valuable information however preventability of the errors should also be taken into consideration. Generally in the current medication error classification systems, if an error occurs more, then initial improvements focused on this error. Consequences of one error can be quite important however if it can prevent easily than the huge effect can be created in terms of safety. What is more, in some institutions because of the lack of employee trainings or lack of control mechanisms, some errors can occur more frequently. From this point of view, considering preventability changes the prioritization thus preventive actions can be planned in a more organized level.

Proposed method is clearly proves that preventability of each error directly effects the prioritization of errors. According to the results, method suggested to focus on “Narcotic/ controlled drug discrepancy(x_4)” and “Other(x_{10})” categories in the 2nd and 3rd place which have also an increasing trend. It is seen that priority of the “Presentation(x_9)” and “Storage/wastage/security(x_5)” also increased based on the results.

4.4. Limitations and Future Studies

In this study, a new patient safety management model is presented in which errors are evaluated based on their severity, preventability and frequency scores. However to indicate the correct scores the main input of the system is having a reliable error reporting mechanism and patient safety culture in the health institution.

In the selected health institution, there is already a proper environment for patient safety since the related hospital is accredited by an international commission. Thus, data which is used in the analysis can be considered as appropriate. The second point, having a reliable error reporting mechanism” is an important issue for every health institution. The underlying reason is that, the structure of the reporting mechanisms can be changed based on the environment of the health institution and the behavior of administrations. From this point of view, this variation in reporting mechanisms can cause limitation in

other studies.

The proposed model provides valuable information and changes the ranking of errors as it is proven in analysis parts of the study. However, it is not possible to reach logical results without correct information in terms of frequency. For that reason, importance weights calculation is also added to analyses to overcome this problem.

On the other hand, simulation models can be used to increase the efficiency of reporting mechanisms. In the current literature, there are many studies try to modify reporting systems considering several scenarios (Anderson and Abrahamson, 2006; 2017; Oostrum, et al., 2008; Wet et al, 2013; Devapriya, et al., 2015; Urbine, et al., 2014). Currently, many of these efforts are focusing only medication related errors since creation of simulation scenarios are easier than other type of errors. Therefore, it is planned to conduct a literature review on simulation modelling in patient safety as a further study. Afterwards, it is planned to develop a simulation model to achieve a better reporting mechanism in which the proposed model is used for overall calculations.

Another study which is planned to conduct as a future study is development an online platform for patients to observe hospitals performances in terms of patient safety. Main aim of the online platform would be provide an information to patients about the performance of hospitals in medical error, error class or department base. Thus, patients can choose the appropriate hospital for themselves and the platform provide an impulse in the quality improvements of the hospitals. Since the role of patients is a critical element for each hospital, benchmarking between hospitals would increase the efforts to achieve quality levels and supports continuous improvement of healthcare processes.

5. CONCLUSION

Lapses in patient safety and quality have substantial costs, in terms of both the effect on people's lives and finances. Globally, the personal and financial impact of patient safety errors is considerable. In the financial year 2017–2018, admissions associated with hospital-acquired complications (HACs) were estimated by the Australian Commission on Safety and Quality in Health Care to cost the public sector \$4.1 billion or 8.9% of total hospital expenditure. Globally, in 2017, it is estimated that global healthcare spend projected to reach \$8.7 trillion by 2020 and spending rates for the world's major regions increases from 2.4 percent to 7.5 percent.

Nowadays, all levels of healthcare have a perspective about the importance of quality in healthcare and hospitals are extended their vision in the light of quality issues. There are an increased focus and some indications of improvement on patient safety issue in recent years however still 1 in 10 patients develop an adverse event. In this context, quality, efficiency, attainability and economically are sought in services to meet patients' individual demands.

Although 19 years past and thousands of papers published, patient safety field is still maintaining its vital position. In some international reports it is seen that patient safety is still at the beginning of its evolution. Today, patient safety can be described as the whole prevention actions taken by the medical establishment to avoid the harm that is given during healthcare services. It composes the primary and indispensable requirement of well-qualified healthcare service since warranting patient safety and preventing medical errors are found in priorities at each step of medical care services. Medical errors affect the patients, the nurses, and the healthcare establishments negatively. Therefore, all members of the healthcare service should be attentive. In this context, warranting patient safety and preventing medical faults appear to be one of the basic elements of quality in healthcare service.

Determination of the medical errors at the right time and revealing the core reasons is a vital part of the solution. In order to give well-qualified healthcare service, medical establishments should meet basic requirements, should apply the process of patient safety perfectly in a flawless way, and should perform the processes with the appropriate procedure. It is a common understanding that improving patient safety is a complex problem that requires collaborative work by diverse disciplines. From the healthcare sector point of view, there is an urgent need to investigate and identify the

critical components to achieve effective healthcare services. In every medical intervention, even if it is maintained correctly, there was a possibility of error, complication (calculated risk) and adverse effect share, depending on the underlying cause. It is not possible to eliminate the risk of medical intervention but it is necessary to weigh the risks before the decision stage.

It is a well-known fact that competitiveness among healthcare organizations highly depends on the patient. Their perceptions can shape with responding to patient views and needs, continuous healthcare service improvement and overall doctor-patient relationship. Thus, in healthcare, not only clinical issues should be investigated in detail but also management and relationships issues should be considered in terms of quality management.

In this study, an index system is developed for the management of patient safety in which all medical errors are evaluated in terms of severity, preventability and occurrence/frequency criteria. In the current situation, generally reported number of events is the only dimension that is considered when prioritizing the errors. If the reported number of errors is high then the related error gains much more priority among others and improvements are planned base on this ranking. However, as it is mentioned before and clearly seen from the analyses, it is not suitable to evaluate risks based only on the frequency, especially for healthcare institutions. When the severity and the preventability of the errors are evaluated, ranking completely changes. In this regard, the study not only contributed to the current literature via generating a method in which three dimensions are taken into consideration at the same time but also it offers a practical measurement system to the health institutions. In this model medical error list provided by the Ministry of Health Turkey is used however it is also possible to adapt different medical errors lists easily.

In the future, as the healthcare system reforms, patient safety should remain a top priority. Day by day, more organizations are adopting new systems to reach high-quality levels, achieving improvements in medication safety and trying to improve the patient safety culture. However, Grepperud (2005) stated that current reporting systems have problems in collecting and analyzing data so it is effected the development of systematic safety strategies. Patient safety issue is important in terms of given the increased efforts to limit health costs and care management. From this framework, in the near future, healthcare will be put under pressure to offer a high level of quality, safety and customer service continuously while ensuring improved efficiency.

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APPENDICES

Appendix 1a (English Version): IMPORTANCE GRADING

Patient safety means preventing the mistakes in the health processes from causing unnecessary harm to the patient and the healthcare worker, or avoiding the potential harm, and includes the measures taken to prevent the harm of health services to individuals.

In order to ensure that errors are identified, reported, and corrected before reaching patients and healthcare professionals, the characteristics of the errors must be evaluated. In this study, the relevant errors are examined in terms of risk, preventability level and frequency of incidence.

We need the opinions of you, the valuable participants, in order to obtain a correct and meaningful result with the planned work.

- **Severity:** It represents the effect of the harm that the related error will have on the patient or healthcare worker. For this category, you are asked to state your opinion on how important the impact level is in the evaluation of errors.
- **Preventability:** Represents how the relevant error can be prevented before it reaches the patient or healthcare professional. For this category, you are asked to indicate your opinion about how important the level of preventability is in the evaluation of errors.
- **Frequency /Occurrence:** Represents the number of times the relevant error is encountered in an institution (the number of patients or healthcare professionals it affects). For this category, you are asked to indicate your opinion about how important the level of incidence in the evaluation of errors.

Thank you for expressing your views using the criteria presented...

***Demographic Information**

Job:

Sector /Industry:

How many years have you been working?:

FIRST PART

In the first part of the questionnaire, you are asked to rate the importance of the risk, preventability and frequency of incidence criteria, which are explained above. Your answer (s) in this question represents which of the relevant criteria is more important to you. Please rate your rating out of 10. (1: Error related to the evaluation criteria is not important at all and 10: importance of relationships to represent the essential criteria for evaluation for error increases towards 10 to 1.)

(It is obligatory to make at least one rating ... the same question will appear **three times for your different views.** If you have more than one different view, you can fill in the other alternatives or leave the page down to move forward to the second part of the questionnaire.)

Question 1: Please evaluate the importance of the mentioned criteria over 10 for any type of error that may occur in terms of patient safety. (Total of your evaluations should be 10)

Severity:

Preventability:

Frequency:

If you have any other opinion than your assessment for Question 1, please fill in the second evaluation section below. Otherwise, go to the next question by sliding the page.

Please evaluate the importance of the mentioned criteria over 10 for any type of error that may occur in terms of patient safety. (Total of your evaluations should be 10)

Severity:

Preventability:

Frequency:

If you have any other opinion than the two different evaluations you made for Question 1, please fill in the third evaluation section below. Otherwise, go to the next question by sliding the page.

Please evaluate the importance of the mentioned criteria over 10 for any type of error that may occur in terms of patient safety. (Total of your evaluations should be 10)

Severity:

Preventability:

Frequency:

SECOND PART

In the second part of the survey, you are asked to rate your 1 or more significance ratings made in the first part. Your answer to this question represents the strength of your opinion on the ratings you have specified.

(For example, if you have made only 1 rating, then your score on the 1st rating should be 100 out of 100, the others should be 0. On the other hand, if you have made 2 or 3 ratings, you should score your opinions by giving them a higher score, which is more accurate for you.)

Please rate your rating suggestions in the previous section out of 100. (Total of your evaluations must be 100)

1. Rating:

2. Rating:

3. Rating:

Please indicate if you have any additional comments on the rating recommendations stated. Otherwise, you can leave the blank and complete the survey.

Appendix 1b (Turkish Version): ÖNEM DERECELENDİRME

Hasta güvenliği, sağlık süreçlerindeki hataların, hasta ve sağlık çalışanına gereksiz zarar vermesini engelleme veya olası zarar görme durumundan uzak olunması anlamına gelmekte ve sağlık hizmetlerinin kişilere vereceği zararı önlemek amacıyla alınan önlemleri kapsamaktadır.

Hataların hasta ve sağlık çalışanlarına ulaşmadan belirlenmesini, raporlanmasını, düzeltilmesini sağlamak amacıyla hataların özelliklerinin değerlendirilmesi gerekmektedir. Bu çalışmada ilgili hatalar risk, önlenabilirlik seviyesi ve görülme sıklığı kriterleri açısından incelenmektedir.

Planlanan çalışma ile doğru ve anlamlı bir sonuç elde edebilmek adına siz değerli katılımcıların görüşlerine ihtiyaç duymaktayız.

- **Risk:** İlgili hatanın hasta veya sağlık çalışanı üzerinde yatacağı zararın etkisini temsil etmektedir. Bu kategori için, hataların değerlendirmesinde etki seviyesinin ne kadar önemli olduğuna dair düşüncelerinizi belirtmeniz istenmektedir.
- **Önlenbilirlik:** İlgili hatanın hasta veya sağlık çalışanına ulaşmadan nasıl önlenilebileceğini temsil etmektedir. Bu kategori için, hataların değerlendirmesinde önlenebilirlik seviyesinin ne kadar önemli olduğuna dair düşüncelerinizi belirtmeniz istenmektedir.
- **Görülme Sıklığı (Frekans):** İlgili hatanın bir kurumda karşılaşılma sayısını (etki ettiği hasta veya sağlık çalışanı sayısını) temsil etmektedir. Bu kategori için, hataların değerlendirmesinde görülme sıklığı seviyesinin ne kadar önemli olduğuna dair düşüncelerinizi belirtmeniz istenmektedir.

Sunulmakta olan kriterleri kullanarak görüşlerinizi belirttiğiniz için teşekkür ederiz...

*Demografik Bilgiler

Mesleğiniz:

Çalışmakta olduğunuz sektör:

Kaç yıldır çalışıyorsunuz?:

BİRİNCİ BÖLÜM

Anketin birinci bölümünde sizden yukarıda açıklamaları sunulmakta olan risk, önlenabilirlik seviyesi ve görülme sıklığı kriterlerinin önemini derecelendirmeniz istenmektedir. Bu soruda vereceğiniz cevap (lar) ilgili kriterlerden hangisinin sizin için daha önemli olduğunu temsil etmektedir.

Lütfen derecelendirmenizi 10 üzerinden puanlayınız. (1: Hata değerlendirmesi için ilgili kriter hiç önemli değil ve 10: Hata değerlendirmesi için ilgili kriter olmazsa olmaz ilişkisini temsil etmek üzere önem derecesi 1'den 10'a doğru artmaktadır.)

(En az bir adet derecelendirme yapılması zorunludur...Öte yandan farklı görüşleriniz için **aynı soru üç kez karşınıza çıkacaktır**.Birden fazla farklı görüşünüz olması durumunda diğer alternatifleri doldurabilir ya da boş bırakarak anketin ikinci bölümüne ilerlemek için sayfayı aşağı kaydırabilirsiniz.)

Soru 1: Lütfen hasta güvenliği açısından oluşabilecek herhangi bir hata türü için bahsedilen kriterlerin önemini 10 üzerinden değerlendiriniz. (Değerlendirmelerinizin toplamı 10 olmalıdır)

Risk:

Önlenbilirlik:

Görülme sıklığı (Frekans):

Appendix 2a (English Version): DETERMINATION OF RISK LEVEL

ERROR CLASSIFICATION SYSTEM DETERMINATION OF RISK LEVEL

(* Mandatory to answer)

Severity Level		Preventability Level	
Coding	Definition	Coding	Definition
1	Without repercussion for the patient	1	Easily Preventable (control charts etc.)
2	Adverse events contributed to temporary harm to the patient and intervention was needed	2	Can be preventable with small system improvements
3	Contributed to the temporary harm to the patient, thereby resulting in longer admission.	3	Can be preventable with trainings
4	Contributed to or resulted in permanent harm to the patient	4	Can be preventable with radical improvements
5	Intervention was needed to keep the patient alive.	5	Unpreventable but side effects can be preventable
6	Contributed to the death of the patient.	6	Unpreventable

*LABORATORY ERRORS

Preanalytic, Analytic and Postanalytic sub-errors

	Severity Level	Preventability Level
Wrong test request		
Missed/wrong information in test request		
Unorganized pathology request form		
Unrecorded sample		
Wrong record		
Sampling from the wrong patient		
Incorrect sample identification		
Missing sample		
Recollected sample		
Incorrect sample container/tube		
Empty sample container/tube		
Sampling with expired tubes		
Not barcoded sample		
Cancellation of the record because a sample could not be obtained from the patient		
Inappropriate taken sample		
Insufficient sample		
Sample with hemolysis		
Clotted sample		
Lipemic sample		
Icteric sample		
Unsent sample in fixative		
Time of sampling is not saved		
Undelivered sample in the laboratory		
Inappropriate transfer conditions		

Exceeding the determined maximum transfer duration of the sample		
Mixing of samples		
Acceptance of the samples that should be rejected		
Automation failure		
Inappropriate stored sample		
Determination of expired kit		
Determination of expired material		
Requested material/kit is not arrived		
Arrived material/kit is wrong		
Inappropriate material transfer conditions		
Inappropriate stored material		
Inappropriate temperature of laboratory		
Undone device maintenance		
Inappropriate preparation of medium		
Equipment failure		
Equipment strawing failure		
Insufficient homogenization of the sample		
Failure to follow test procedures		
Seeding failure		
Nonconformity of external quality control studies		
Working with improper quality control outputs		
Not working with internal quality control		
Inappropriate incubation temperature		
Inappropriate incubation period		
Inappropriate pigmentation technique		
Improper dilution		
Using improper solution		
Incorrect evaluation of the result		
Incorrect technical approval		
Incorrectly entered report results		
Incorrect report		
Unsaved patient reports		
Results that are not given in time		
Lately reported panic value		

***MEDICATION ERROR**

Storage, Demanda, Preparation, Transfer, Implementation and Post-implementation sub-erros

	Severity Level	Preventability Level
Inappropriate temperature and humidity		
Violation of FIFO rule		
Light exposure		

Confusion in selection because of the similarity in writing, reading or appearance of the drugs		
Pediatric doses are on the same shelf with other drugs		
Failure in controlling of critical stock level		
Faulty expiration date and critical stock level warning system		
Undefined high-risk drugs		
Undefined psychotropic and narcotic drugs		
Stolen drugs		
Loss of drugs		
Expired drugs		
Wrong drug demand		
Wrong drug selection in electronic system		
Choosing wrong treatment		
Writing contraindicated drugs		
Using abbreviation in drug name		
Illegible handwriting		
Erroneous dosing		
Misunderstanding of verbal demand		
Unwritten verbal demand		
Lack of communication		
Misinterpretation of doctor's demand		
Preparation of wrong drug		
Incorrect packaging of drugs		
Incorrect labelling of drugs		
Undefined medicines that brought by the patient		
Unimplemented hand hygiene		
Drug incompatibility		
Preparing the medicine with the wrong technique		
Confusion in selection because of the similarity in writing, reading or appearance of the drugs		
Incorrect labelling of prepared drugs		
Drug application without doctor request		
Unauthorized drug application		
Impaired drug application		
Presence of medication near the patient		
Inaccurate information about the use of medicine		
Not informing the patient about the use of the medicine		
Prepared medicines sent to the wrong patient		
Distribution of drugs at the wrong time		
Transferring wrong drug from pharmacy		
Wrong delivery of medicines		

Do not send drugs to patients / department on time		
Unimplemented hand hygiene		
Failure to comply with sterilization / disinfection rules		
Wrong patient		
Wrong drug		
Wrong dosage (high)		
Wrong dosage (low)		
Wrong pharmaceutical form		
Wrong time		
Wrong methodology		
Applying incompatible drugs at the same time		
Skipping a dosage		
Repeated drug administration		
Incorrect application period (Injection)		
No hand hygiene after drug application		
Drug application not recorded		
Non-removal of wastes after drug application		
No observations after drug administration		
Adverse effect (management not defined)		
Adverse effect (Notification)		
Not observed drug-drug, drug-food interaction		
Original packaging of the returned medicine is broken		

***GENERAL/SURGICAL ERRORS**

Clinical Surgical Procedure Preparation, Transfer to the Operating Room and Patient Acceptance, Operating Room Surgical Procedure, Pre-Anesthesia Preparation and Control, Controls Before Surgery, Follow-up and Control During Operation, Controls at the End of the Operation, Departure of the patient from the operation room and transfer sub-errors

	Severity Level	Preventability Level
Non-Marking of operation area / side		
Not controlling marking of the operation area / side		
Pre-op fasting requirement not confirmed		
The operation area has not been shaved		
Not confirming removal of make-up, prosthesis and valuable items		
Skipping pre-operative special procedure (enema application etc.)		
Failure to control supply of supplies and blood / blood products for surgery		
Do not check that examination and surveys are near the patient		
Not receiving patient's consent		
Not controlling the receive of patient's consent		
Unverified Patient ID, location of operation and surgical procedure		
Health worker does not accompany patient transfer		
Do not deliver the patient to the health worker		
Failure to transmit information about the operation during delivery		

Failure of cleaning of operation room and surgical table		
Not controlling of anesthesia devices and equipment		
Equipment malfunction due to lack of calibration / maintenance		
Do not check that the outlets are connected to uninterruptible power supply		
Not performing particle counting / checking		
Inadequate control of room temperature and humidity		
Not controlling the medical gas system		
Unverified Patient ID, location of operation and surgical procedure		
Not controlling the receive of patient's consent		
Not controlling marking of the operation area / side		
Pulse oximeter device not on patient and not controlled		
Unevaluated allergy status		
Not evaluating the necessity of blood transfusion		
Not controlling the display devices that may be needed		
Unresolved anesthesia risks		
Unverified Patient ID, location of operation and surgical procedure		
Team members do not identify themselves		
Critical events that can occur due to surgery are not evaluated		
Unevaluated critical event that can occur due to anesthesia		
Do not check that the materials are ready and sterile		
Not applying the required surgical prophylaxis		
Unevaluated blood sugar control necessity		
Unquestioning of the use of anticoagulants		
Do not apply the required DVT prophylaxis		
No patient compliance check when blood / blood product use is required		
No appropriate labeling of the sample when frozen is required		
Unverified Patient ID, location of operation and surgical procedure		
Uncontrolled instrument, sponge, compress and needle counts that are used		
Not properly labelled receipt samples		
Unrecognized possible surgical critical care requirements		
Potential anesthesia critical maintenance requirements not assessed		
Not specifying the part of the post-op patient to be transferred		
Failure to transmit surgical critical care requirements to healthcare personnel who receives the patient		
Patient identity, surgical procedure and the part of the patient to be transferred are not verified		
Do not deliver the patient to the health worker		
Health worker does not accompany patient transfer		

***PATIENT RELATED ERRORS**

Medical Record and Clinic Evaluation Related, Care, Diagnosis and Treatment Process Related, Errors Concerning the Transfusion

of Blood and Blood Products

	Severity Level	Preventability Level
Incorrect identification of patients		
Delivering someone else's receipt to the patient		
Wrong delivery of the newborn		
Incorrect handling of medical records about the applied care or treatment		
Illegible evaluation / consultations notes		
Missing / Wrong evaluation / consultations notes		
Incorrect record of patient basic information		
Complication developed in the patient due to maintenance / treatment delay		
Complication developed in the patient due to consultation delay		
Patient care plan not determined according to patient needs		
No evaluation of the patient in terms of nutrition		
No asepsis / sterilization / isolation requirements for care		
Misassignment of assay and test results		
Confirmation of patient identity before treatment / care		
Patient Fall		
Unsuitable patient delivery		
Late intervention for blue code status		
Late intervention in pink code condition		
Late intervention in red code condition		
Infringement of patient privacy		
Patient safety not provided		
Application with medical device filled with calibration period		
Formation of 3rd level and higher pressure ulcer in patient in hospitalization period		
Late detection of hyperbilirubinemia in the newborn		
Late detection of hypoglycemia in the newborn		
Late detection of premature retinopathy in the newborn		
Giving the wrong blood / blood product to the patient		
Failure to provide the necessary protective equipment to the patient during medical imaging		
Not monitoring of complications developing after care or treatment		
Not confirmed patient identity		
Lack of records of transfusion request		
Not checking product information (Blood group, Cross-match, SKT, Tests etc.)		
Product label information is incorrect		
Incorrect transfer of blood product		
Incorrect application of blood product		
Failure to observe patients properly before and after the procedure		

*** PATIENT RELATED ERRORS**

Errors Regarding Nutrition Patient / Attendant Related and Communication Errors

	Severity Level	Preventability Level
Not evaluated nutritional status of the patient		
Unquestioned food allergy story of the patient		
Improper nutritional support or diet choice for the patient		
Giving the wrong food to the patient		
Food brought to the patient from outside the facility		
Food poisoning		
Inadequate nutrition of the patient during treatment		
Overfeeding of the patient during the treatment process		
Incorrect preparation of PN suspension		
Incorrectly protected PN suspension		
Incorrect application of PN suspension		
PN suspension given to the wrong patient		
Maintenance-induced TPN catheter infection		
Not informing the patient about nutrition while being discharged		
Suicide attempt resulting in serious injury or death		
The patient's health condition causes harm to other patients		
Patient Falls		
The patient does not follow the care / treatment guidelines in the hospitalization process		
Removal / replacement of the identity by the patient without informing healthcare professional		
Changing the bed without the healthcare provider's knowledge		
Use of medication / nutrition / food supplement without the healthcare staff's knowledge		
The patient does not fulfill preoperative requirements		
Departure from the health facility without the knowledge of the hospital's health personnel		
Providing incomplete / misleading information about the patient's health histories		
The refusal of compulsory education by the patient or accompanying persons		
Formation of 3rd level pressure after the discharge		
The patient does not come to control after discharge		
The patient does not follow post-discharge care / treatment guidelines		
Uninformed patient about the care, diagnosis method or treatment		
Missing/ Lack of information about the care, diagnosis method or treatment		
Care and treatment after hospitalization		

*** PATIENT RELATED ERRORS**

Physical Structure Related or Device/Equipment/System Related Errors

	Severity Level	Preventability Level
Patient stuck in the elevator due to the malfunction		
Patient fall/injured due to the elevator malfunction		
Patient fall/injured due to the escalator malfunction		
Patient fall/injured due to the slippery floors		
The absence of a disaster and emergency plan		
Lack of emergency and disaster management guidance		
Missing /Not found patient instruction marks		
Lack of elderly or disabled patient instructions		
Medical gas contamination or incorrect gas mixture		
Injured patients due to the electric leakage		
Injured patients due to the fire /explosion		
Contamination of water resources		
Flood / Sewage flood		
Exposure to hazardous waste /material except for diagnosis / treatment purposes		
Absence of noise control in the intensive care unit		
Basic facility resource related backup systems didn't started in time		
Injured patient due to the movement restriction equipment		
Unprovided asepsis conditions due to the lack of infrastructure / equipment		
Untimely repaired / replaced defective equipment		
Untimely made device calibration and /or tests		
Lack of care, diagnosis and treatment process related equipment		
Injured patient due to the device failure		
Lack of internal safety or sentinel event reporting system		
Untimely interfere to the sentinel event notifications		
Not evaluated internal safety report notifications		
Failure to provide training about the emergency and disaster management		
Not evaluated patient complaints and feedbacks		
Loss of patient information data because of the safety problem in information network		
Stolen patient information data because of the safety problem in information network		
Patient Fall		

Appendix 2b (Turkish Version): RİSK SEVİYESİ BELİRLEME

HATA SINIFLANDIRMA SİSTEMİ RİSK SEVİYESİ BELİRLEME

(* İşareti ile başlayan sorular zorunludur.)

Kodu	Tanımı	Kodu	Tanımı
1	Hastaya bir etkisi olmaz	1	Kolayca önlenabilir
2	Geçici zarar oluşur, basit müdahale gerekir	2	Kolay sistem iyileştirmeleri ile önlenabilir
3	Geçici zarar oluşur, hastanede daha uzun kalınması gerekir	3	Eğitim düzenlenerek önlenabilir
4	Kalıcı zarar oluşmasına sebebiyet verir	4	Radikal sistem iyileştirmeleri ile önlenabilir
5	Hastayı hayatta tutabilmek için müdahale gerekir	5	Önlenemez ama yan etkileri engellenebilir
6	Ölüme sebebiyet verir	6	Önlenemez

*LABORATUVAR HATALARI

Preanalitik, Analitik ve Postanalitik evreleri kapsamaktadır

	Risk Seviyesi	Önlenbilirlik Seviyesi
L01 Hatalı test istemi		
L02 Test isteminde eksik/yanlış bilgi		
L03 Patoloji istek formunun düzenlenmemesi		
L04 Kayıtsız numune		
L05 Hatalı kayıt		
L06 Yanlış hastadan numune alınması		
L07 Hatalı kimliklendirilmiş numune		
L08 Kaybolan numune		
L09 Tekrar alınan numune		
L10 Hatalı numune kabı/tüpü		
L11 Boş numune kabı/tüpü (içinde numune yok)		
L12 Son kullanma tarihi geçmiş tüplere numune alınması		
L13 Barkodsuz numune		
L14 Hastadan numune alınamaması nedeni ile kaydın iptal edilmesi		
L15 Uygunsuz alınmış numune		
L16 Yetersiz numune		
L17 Hemolizli numune		
L18 Pıhtılı numune		
L19 Lipemik numune		
L20 İkterik numune		
L21 Numunenin fiksatif içinde gönderilmemesi		
L22 Numune alma zamanının kaydedilmemesi		
L23 Laboratuvarda teslim edilmeyen numune		
L24 Uygunsuz transfer koşulları		
L25 Belirlenen maksimum numune transfer süresinin aşılması		
L26 Numunelerin karışması		

L27 Reddedilmesi gereken numunenin kabulü		
L28 Otomasyon arızası		
L29 Uygunsuz saklanmış numune		
L30 Miadı geçmiş kit tespiti		
L31 Miadı geçmiş malzeme tespiti		
L32 İsteği yapılan malzeme/kit gelmemesi		
L33 Yanlış malzeme/kit gelmesi		
L34 Malzeme transferinin uygun şartlarda yapılmaması		
L35 Malzemenin uygun koşullarda saklanmaması		
L36 Laboratuvar ortam ısının uygunsuzluğu		
L37 Cihaz bakımlarının yapılmaması		
L38 Besiyerinin uygun hazırlanmaması		
L39 Cihaz arızası		
L40 Cihaz pipetasyon hatası		
L41 Numunenin yetersiz homojenizasyonu		
L42 Test çalışma prosedürlerine uyulmaması		
L43 Ekim hataları		
L44 Dış kalite kontrol çalışmalarında uygunsuzluk		
L45 Uygunsuz kalite kontrol sonucu ile çalışılması		
L46 İç kalite kontrol çalışılmaması		
L47 Uygunsuz inkübasyon sıcaklığı		
L48 Uygunsuz inkübasyon süresi		
L49 Uygunsuz boyama tekniği		
L50 Uygunsuz dilüsyon		
L51 Uygunsuz solüsyon kullanılması		
L52 Sonucun yanlış değerlendirilmesi		
L53 Hatalı teknik onay		
L54 Sonuçların sisteme hatalı girilmesi		
L55 Hatalı rapor		
L56 Hasta raporlarının kaybedilmesi		
L57 Zamanında verilmeyen sonuç		
L58 Panik değerin geç bildirilmesi		

***İLAÇ HATALARI**

Muhafaza, İstem, Hazırlama, Transfer, Uygulama ve uygulama sonrası evreleri kapsamaktadır.

	Risk Seviyesi	Önlenebilirlik Seviyesi
Sıcaklık ve nem uygunsuzluğu		
İlk gelen ilk çıkar (FIFO) kuralı ihlali		
Işık maruziyeti		
Yazılışı, okunuşu, görünümü benzer ilaçların karışması		
Pediyatrik dozdaki ilaçların diğer ilaçlar ile aynı rafta olması		
Kritik stok seviyesinin hatalı kontrolü		

Miat ve kritik stok seviyesi uyarı sisteminin hatalı olması		
Yüksek riskli ilaçların tanımlanmaması		
Psikotrop ve narkotik ilaçların tanımlanmaması		
İlacın çalınması		
İlacın kaybolması		
Miadi dolmuş ilaç		
Yanlış ilaç istemi		
Elektronik ortamda yanlış ilaç seçimi		
Kontrendike ilaç yazılması		
İlaç adında kısaltma kullanımı		
Okunaksız el yazısı		
Hatalı doz istemi		
Sözel istemin yanlış anlaşılması		
İletişim eksikliği		
Doktor isteminin yanlış yorumlanması		
Yanlış ilaç hazırlanması		
İlaçların yanlış paketlenmesi		
İlaçların yanlış etiketlenmesi		
Hastanın yanında getirdiği ilaçların tanımlanmaması		
El hijyeni uygulanmaması		
İlaç geçimsizliği		
İlacın yanlış teknik ile hazırlanması		
Doktor istemi dışında ilaç uygulanması		
Yetki dışında ilaç uygulanması		
Bozulmuş ilaç uygulanması		
Hasta başında ilaç bulundurulması		
İlacın kullanımı hakkında hastaya yanlış bilgi verilmesi		
İlacın kullanımı hakkında hastaya bilgi verilmemesi		
Hazır ilaçların yanlış hastaya gönderilmesi		
Yanlış zamanda ilaç dağıtılması		
Eczaneden yanlış ilacın transferi		
İlaçların yanlış birime gönderilmesi		
İlaçların hastaya/birime zamanında gönderilmemesi		
Sterilizasyon/dezenfeksiyon kurallarına uyulmaması		
Yanlış hasta (Uygulama Aşamasında)		
Yanlış ilaç (Uygulamam Aşamasında) (Uygulama Aşamasında)		
Yanlış doz (Aşırı) (Uygulama Aşamasında)		
Yanlış doz (Yetersiz) (Uygulama Aşamasında)		
Yanlış farmasötik form (Uygulama Aşamasında)		
Yanlış teknik (Uygulama Aşamasında)		
Doz atlama (Uygulama Aşamasında)		

Mükerrer ilaç verme (Uygulama Aşamasında)		
Yanlış uygulama süresi (Enjeksiyon)		
Yanlış uygulama süresi (İnfüzyon)		
İlaç uygulamasının kayıt altına alınmaması		
İlaç uygulama sonrası atıkların ortamdaki uzaklaştırılmaması		
İlaç uygulama sonrası gözlem yapılmaması		
Advers etki (Yönetiminin tanımlanmaması)		
Advers etki (Bildirim yapılmaması)		
İlaç-ilaç, ilaç-besin etkileşiminin gözlenmemesi		
İade edilen ilaçların orijinal ambalajının bozulmuş olması		

***CERRAHİ HATALAR**

Klinik Cerrahi İşlem Hazırlığı, Ameliyathaneye Transfer ve Hasta Kabulü, Ameliyathane Cerrahi İşlem Hazırlığı, Anestesi Öncesi Hazırlık ve Kontroller, Ameliyat Sürecindeki ve Sonu Takip ve Kontroller, Ameliyathaneden Hastanın Ayrılışı ve Transferi evrelerini kapsamaktadır.

	Risk Seviyesi	Önlenebilirlik Seviyesi
Ameliyat bölgesinin/tafının işaretlenmemesi		
Ameliyat bölgesinin/tafının kontrol edilmemesi		
Pre-op açıklık gerekliliğinin teyit edilmemesi		
Ameliyat bölgesinin tıraşının yapılmamış olması		
Makyaj, protez ve değerli eşyalarının çıkarıldığına teyit edilmemesi		
Ameliyat öncesi özel işlemin(lavman uygulaması vb.) atlanması		
Ameliyat için gerekli malzeme, kan/kan ürünlerinin tedarik kontrolünün yapılmaması		
Tetkik ve tahlillerin hasta yanında olduğunun kontrol edilmemesi		
Hasta rızasının alınmaması		
Hasta rızasının kontrol edilmemesi		
Hasta kimliği, ameliyat yeri ve cerrahi işlemin doğrulanmaması		
Hasta transferine sağlık çalışanının eşlik etmemesi		
Hastanın sağlık çalışanına teslim edilmemesi		
Teslim sırasında ameliyat sürecine ait bilgilerin iletilmemesi		
Ameliyat odasının ve ameliyat masasının temizliğinin uygun olmaması		
Anestezi cihaz ve ekipmanlarının kontrol edilmemesi		
Kalibrasyon/bakım eksikliğinden kaynaklanan ekipman arızası		
Prizlerin kesintisiz güç kaynağına bağlı olduğunun kontrol edilmemesi		
Partikül ölçümlerinin yapılmaması/kontrol edilmemesi		
Oda sıcaklığı/nemin uygunsuzluğu/kontrol edilmemesi		
Tıbbi gaz sisteminin kontrol edilmemesi		
Pulse oksimetre cihazının hasta üzerinde olmaması/kontrol edilmemesi		
Alerji durumunun değerlendirilmemesi		

Kan transfüzyonu gerekliliğinin değerlendirilmemesi		
İhtiyaç duyulabilecek görüntüleme cihazlarının kontrol edilmemesi		
Anestezi risklerinin değerlendirilmemesi		
Ekip üyelerinin kendini tanıtmaması		
Cerrahi kaynaklı gerçekleşebilecek kritik olayların değerlendirilmemesi		
Anestezi kaynaklı gerçekleşebilecek kritik olayların değerlendirilmemesi		
Malzemelerin hazır ve steril olduğunun kontrol edilmemesi		
Gerekli cerrahi profilaksinin uygulanmaması		
Kan şekeri kontrolü gerekliliğinin değerlendirilmemesi		
Antikoagülan kullanımının sorgulanmaması		
Gerekli DVT-profilaksisinin uygulanmaması		
Kan/kan ürünü kullanımı gerektiğinde hastaya uygunluk kontrolünün yapılmaması		
Frozen gerektiği durumda numunenin uygun şekilde etiketlenmemesi		
Kullanılan alet, spanç, kompres ve iğne sayımlarının kontrol edilmemesi		
Alınan numunelerin uygun şekilde etiketlenmemesi		
Olası cerrahi kritik bakım gereksinimlerinin değerlendirilmemesi		
Olası anestezi kritik bakım gereksinimlerinin değerlendirilmemesi		
Post-op hastanın transfer edileceği bölümün belirtilmemesi		
Cerrahi kritik bakım gereksinimlerinin hastayı teslim alan sağlık personeline iletilmemesi		
Hasta kimliği, cerrahi işlem ve hastanın transfer edileceği bölümün doğrulanmaması		

***DİĞER HATALAR**

Tıbbi Kayıt,Kimlik Değerlendirme, Bakım, Teşhis ve Tedavi Sürecine ve Kan ve Kan Ürünlerinin Transfüzyonuna İlişkin Hatalar

	Risk Seviyesi	Önenebilirlik Seviyesi
Hastanın yanlış kimliklendirilmesi		
Hastaya yanlış kişiye ait reçetenin verilmesi		
Yeni doğanın yanlış kişiye teslimi		
Yapılan bakım/tedavinin tıbbi kayıtlara hatalı işlenmesi		
Değerlendirme/konsültasyon notlarının okunaksız olması		
Değerlendirme/konsültasyon notlarının eksik/hatalı olması		
Hastanın temel bilgilerinin yanlış kaydedilmesi		
Yaşlı veya engelli hastalara yönelik düzenlemelerin eksik olması		
Bakım/tedavi gecikmesine bağlı olarak hastada komplikasyon gelişmesi		
Konsültasyon gecikmesine bağlı olarak hastada komplikasyon gelişmesi		

Hasta bakım planının hasta ihtiyaçlarına göre belirlenmemesi		
Hastanın nutrisyon açısından değerlendirilmemesi		
Bakım için gerekli asepti/sterilizasyon/izolasyon koşullarının sağlanmaması		
Tahlil ve tetkik sonuçlarının yanlış değerlendirilmesi		
Bakım/tedavi uygulaması öncesinde hasta kimliğinin doğrulanmaması		
Mavi kod durumuna müdahalenin geç yapılması		
Pembe kod durumuna müdahalenin geç yapılması		
Kırmızı kod durumuna müdahalenin geç yapılması		
Arızalı ekipmanın zamanında onarılmaması/değiştirilmemesi		
Hasta mahremiyetinin ihlal edilmesi		
Hasta emniyetinin sağlanmaması		
Kalibrasyon süresi dolmuş tıbbi cihaz ile uygulama yapılması		
Yeni doğanda geç tespit edilen hiperbilirubinemi		
Yeni doğanda geç tespit edilen hipoglisemi		
Yeni doğanda geç tespit edilen prematüre retinopati		
Hastaya yanlış kan/kan ürünü verilmesi		
Tıbbi görüntüleme esnasında hastaya gerekli koruyucu ekipmanın kullanılmaması		
Bakım veya tedavi sonrasında gelişen komplikasyonların izlenmemesi		
Transfüzyon istemine ilişkin kayıtlarda eksiklik bulunması		
Ürün bilgilerinin kontrol edilmemesi (Kan grubu, Cross-match, SKT, Testler vb.)		
Ürünün etiket bilgilerinin hatalı olması		
Kan ürününün birime hatalı transferi		
Kan ürününün hatalı uygulanması		
Süreç öncesi ve sonrasında hasta gözleminin uygun olarak yapılmaması		

***DİĞER HATALAR**

Nutrisyona İlişkin, Hasta/refakatçi Kaynaklı Hatalar ve İletişim Hataları

	Risk Seviyesi	Önlenebilirlik Seviyesi
Hastanın nutrisyon durumunun değerlendirilmemesi		
Hastanın gıda alerji öyküsünün sorgulanmaması		
Hasta için hatalı nutrisyon desteği veya diyet seçimi		
Hastaya yanlış yemeğin verilmesi		
Hastaya tesis dışından yemek/gıda getirilmesi		
Gıda zehirlenmesi		
Tedavi sürecinde hastanın yetersiz beslenmesi		
Tedavi sürecinde hastanın aşırı beslenmesi		
PN süspansiyonunun yanlış hazırlanması		
PN süspansiyonunun yanlış muhafazası		

PN süspansiyonunun yanlış uygulanması		
PN süspansiyonunun yanlış hastaya verilmesi		
Bakım kaynaklı TPN kateter enfeksiyonu oluşması		
Taburculukta hastaya nütrisyon konusunda bilgi verilmemesi		
Ciddi yaralanma veya ölümle sonuçlanan intihar girişi		
Hastanın, sağlık durumu nedeni ile diğer hastalara zarar vermesi		
Hastanın düşmesi		
Hastanın, yatış sürecinde bakım/tedavi yönergelerine uymaması		
Hastanın, sağlık personelinin bilgisi dışında kimlik tanımlayıcısını çıkarması/değiřtirmesi		
Hastanın, sağlık personelinin bilgisi dışında yatađını deđiřtirmesi		
Hastanın, sağlık personelinin bilgisi dışında ilaç/nutrisyon/gıda takviyesi kullanması		
Hastanın, ameliyat öncesi gereklilikleri yerine getirmemesi		
Hastanın, ilgili personele sağlık geđmiři hakkında eksik/yanıltıcı bilgi vermesi		
Hastanın veya refakatçilerin, kendilerine verilmesi zorunlu eđitimleri reddetmeleri/dinlememeleri		
Taburcu sonrası 3. seviye üstü bası ülseri oluşumu		
Hastaya yanlış kan/kan ürünü verilmesi		
Hastanın, taburcu sonrası kontrole gelmemesi		
Hastanın, taburcu sonrası bakım/tedavi yönergelerine uymaması		
Transfüzyon istemine ilişkin kayıtlarda eksiklik bulunması		
Hastanın uygulanan bakım, teřhis metodu veya tedavi konusunda bilgilendirilmemesi		
Hastanın uygulanan bakım, teřhis metodu veya tedavi konusunda hatalı/eksik bilgilendirilmesi		

***DİĐER HATALAR**

Bina Yapısı ile İliřkili veya Cihaz/Ekipman/Sistem Kaynaklı Hatalar

	Risk Seviyesi	Önlenebilirlik Seviyesi
Hastanın asansör arızası nedeni ile mahsur kalması		
Hastanın asansör arızası nedeni ile düşmesi/yaralanması		
Hastanın yürüyen merdiven arızası nedeni ile düşmesi/yaralanması		
Hastanın ıslak/kaygan zemin nedeni ile düşmesi/yaralanması		
Acil durum ve afet planının bulunmaması		
Acil durum ve afet yönetimine ilişkin yönlendirmelerin eksik olması		
Hasta yönlendirme işaretlerinin eksik olması/bulunmaması		
Yařlı veya engelli hastalara yönelik düzenlemelerin eksik olması		
Medikal gaz kontaminasyonu veya yanlış gaz karışımı		
Elektrik kaçađı sonucu hastanın yaralanması		

Yangın/patlama sonucu hastanın yaralanması		
Su kaynaklarının kontaminasyonu		
Su/kanalizasyon baskını		
Teşhis/tedavi amacı dışında hastanın tehlikeli atık/maddelere maruziyeti		
Yoğun bakım ünitelerinde gürültü kontrolünün sağlanmaması		
Temel tesis kaynakları ile ilişkili yedek sistemlerin zamanında devreye girmemesi (su, elektrik, gaz vb.)		
Hareket kısıtlama ekipmanının hastaya zarar vermesi		
Asepsi koşullarının altyapı/ekipman eksikliği nedeni ile sağlanmaması		
Arızalı ekipmanın zamanında onarılması/değiştirilmemesi		
Cihaz kalibrasyon ve/veya testlerinin zamanında yapılmaması		
Bakım, teşhis veya tedavi sürecine ilişkin ekipmanın yetersizliği		
Cihaz arızası nedeni ile hastanın zarar görmesi		
Tesiste sentinel olay veya iç güvenlik raporlama sistemlerinin bulunmaması		
Sentinel olay bildirimlerine zamanında müdahale edilmemesi		
İç güvenlik raporlama bildirimlerinin değerlendirilmemesi		
Acil durum ve afet yönetimine ilişkin eğitimlerin verilmemesi		
Hasta şikayet ve geribildirimlerinin değerlendirilmemesi		
Bilgi ağındaki güvenlik açığı sebebi ile hasta bilgilerinde veri kaybının gerçekleşmesi		
Bilgi ağındaki güvenlik açığı sebebi ile hasta verilerinin çalınması		
Hastanın Düşmesi		

Appendix 3

Laboratory Errors	Severity*Preventability				Laboratory Errors	Severity*Preventability			
	a	b	c	d		a	b	c	d
L01	0,4994813	0,6108908	0,2417929	0,3891092	L31	0,5001772	0,6068102	0,2418718	0,3931898
L02	0,5051743	0,6138018	0,2374729	0,3861982	L32	0,5204296	0,6241279	0,2238621	0,3758721
L03	0,5243478	0,6300292	0,2159573	0,3699708	L33	0,5175109	0,6217977	0,2267901	0,3782023
L04	0,4948964	0,6047314	0,247225	0,3952686	L34	0,5043769	0,6113117	0,2385241	0,3886883
L05	0,4873336	0,5985284	0,2514004	0,4014716	L35	0,5224624	0,6270636	0,2212578	0,3729364
L06	0,5229498	0,6293922	0,2174528	0,3706078	L36	0,5213007	0,62529	0,2228071	0,37471
L07	0,5344605	0,6397085	0,2049587	0,3602915	L37	0,5167838	0,6219902	0,2270092	0,3780098
L08	0,5132282	0,6178925	0,2322862	0,3821075	L38	0,49145	0,6005101	0,2503587	0,3994899
L09	0,4847575	0,5932849	0,2578044	0,4067151	L39	0,5158204	0,6189052	0,2296343	0,3810948
L10	0,4703587	0,5828123	0,2693174	0,4171877	L40	0,5272613	0,6301246	0,219288	0,3698754
L11	0,483565	0,5940949	0,2585322	0,4059051	L41	0,5145799	0,617299	0,2323852	0,382701
L12	0,4937592	0,6044143	0,2473377	0,3955857	L42	0,5120835	0,6188655	0,229895	0,3811345
L13	0,5115333	0,6170222	0,2321792	0,3829778	L43	0,5125644	0,6168923	0,2328251	0,3831077
L14	0,4817411	0,5940434	0,2579538	0,4059566	L44	0,5022545	0,6088354	0,2406192	0,3911646
L15	0,5254673	0,6287463	0,2173266	0,3712537	L45	0,5306937	0,6327871	0,2155322	0,3672129
L16	0,5184706	0,621717	0,2266327	0,378283	L46	0,5188701	0,6205952	0,227858	0,3794048
L17	0,516511	0,6172675	0,2304965	0,3827325	L47	0,5330248	0,6359219	0,2112179	0,3640781
L18	0,5081492	0,6088876	0,2392251	0,3911124	L48	0,5229025	0,6254439	0,2228812	0,3745561
L19	0,5155252	0,6164789	0,230378	0,3835211	L49	0,5022445	0,6066708	0,2429866	0,3933292
L20	0,5247586	0,6258093	0,2207491	0,3741907	L50	0,505353	0,6104157	0,238854	0,3895843
L21	0,5075421	0,6135313	0,2358169	0,3864687	L51	0,5113244	0,6136718	0,2351805	0,3863282
L22	0,4964793	0,6058997	0,2456655	0,3941003	L52	0,5336505	0,6371819	0,2084096	0,3628181
L23	0,4895789	0,5984901	0,2533885	0,4015099	L53	0,5262422	0,6294835	0,2162855	0,3705165
L24	0,5010564	0,6067114	0,2436647	0,3932886	L54	0,5503758	0,6533275	0,1921297	0,3466725
L25	0,5293379	0,634316	0,214368	0,365684	L55	0,5567497	0,6581899	0,1865874	0,3418101
L26	0,5429864	0,647093	0,1976016	0,352907	L56	0,5345679	0,6351789	0,2128166	0,3648211
L27	0,5145134	0,6188096	0,2297156	0,3811904	L57	0,5300413	0,6320196	0,2157629	0,3679804
L28	0,5038659	0,6091707	0,241338	0,3908293	L58	0,5572815	0,6612078	0,1814042	0,3387922
L29	0,519225	0,624569	0,2240186	0,375431					
L30	0,5142671	0,6201014	0,2287192	0,3798986					

Medication Errors	Severity*Preventability				Medication Errors	Severity*Preventability			
	a	b	c	d		a	b	c	d
I0a	0,4895904	0,6023731	0,2504291	0,3976269	I2l	0,5509226	0,6551978	0,1905421	0,3448022
I0b	0,4751229	0,588993	0,265106	0,411007	I2m	0,579649	0,680953	0,1646036	0,319047
I0c	0,5037982	0,6124918	0,2373288	0,3875082	I2n	0,5275197	0,6307599	0,2160807	0,3692401
I0d	0,5683751	0,6697915	0,1746068	0,3302085	I2o	0,5441314	0,6449762	0,2021196	0,3550238
I0e	0,5475485	0,6485781	0,1974691	0,3514219	I2p	0,5356676	0,6366809	0,2098033	0,3633191
I0f	0,4870432	0,5979305	0,2539378	0,4020695	I3a	0,5659269	0,6693107	0,175307	0,3306893
I0g	0,5013712	0,6077198	0,2424783	0,3922802	I3b	0,5342291	0,6352279	0,2117423	0,3647721
I0h	0,5522875	0,6534494	0,192242	0,3465506	I3c	0,5216244	0,6246752	0,2234172	0,3753248
I0i	0,524829	0,6310761	0,2135626	0,3689239	I3d	0,5014233	0,6088706	0,2411692	0,3911294
I0j	0,4697727	0,5834985	0,2703167	0,4165015	I3e	0,5288186	0,6297351	0,2176714	0,3702649
I0k	0,4810852	0,5911206	0,2608589	0,4088794	I4a	0,5278009	0,6335466	0,2103639	0,3664534
I0l	0,5308774	0,6359244	0,21121	0,3640756	I4b	0,566321	0,6706474	0,172742	0,3293526
I1a	0,5177651	0,6193448	0,2290013	0,3806552	I4c	0,5833024	0,6865265	0,1566592	0,3134735
I1b	0,5244546	0,626125	0,2213825	0,373875	I4d	0,5817422	0,6853873	0,1585256	0,3146127
I1c	0,5342287	0,6377632	0,2091237	0,3622368	I4e	0,5832797	0,6870293	0,1565513	0,3129707
I1d	0,5246048	0,6297837	0,2173831	0,3702163	I4f	0,5587424	0,6603499	0,1837047	0,3396501
I1e	0,482832	0,594281	0,2564204	0,405719	I4g	0,5656582	0,66702	0,1779633	0,33298
I1f	0,4958808	0,6041218	0,2437803	0,3958782	I4h	0,5342287	0,6377632	0,2091237	0,3622368
I1g	0,5244943	0,6284659	0,218575	0,3715341	I4i	0,5342287	0,6377632	0,2091237	0,3622368
I1h	0,5331341	0,635693	0,2108087	0,364307	I4j	0,5584816	0,661219	0,1833153	0,338781
I1i	0,5010625	0,6059713	0,2424156	0,3940287	I4k	0,5288913	0,6295943	0,2180997	0,3704057

I1j	0,5010625	0,6059713	0,2424156	0,3940287	I4l	0,5615746	0,6627882	0,1830226	0,3372118
I2a	0,4985431	0,6045951	0,2431458	0,3954049	I4m	0,5499255	0,6510003	0,1952131	0,3489997
I2b	0,5326569	0,6372367	0,2087073	0,3627633	I4n	0,5529801	0,6558109	0,1895005	0,3441891
I2c	0,4997927	0,6082189	0,2393936	0,3917811	I5a	0,5278009	0,6335466	0,2103639	0,3664534
I2d	0,5038562	0,6117255	0,2355608	0,3882745	I5b	0,5327111	0,6336395	0,2132068	0,3663605
I2e	0,5137976	0,6191237	0,2274915	0,3808763	I5c	0,5506299	0,6538627	0,1892413	0,3461373
I2f	0,5278009	0,6335466	0,2103639	0,3664534	I5d	0,5293318	0,6320748	0,2138322	0,3679252
I2g	0,5584816	0,661219	0,1833153	0,338781	I5e	0,5282815	0,6341782	0,2106738	0,3658218
I2h	0,5430238	0,6455108	0,2012317	0,3544892	I5f	0,5332014	0,6393082	0,205088	0,3606918
I2i	0,5683751	0,6697915	0,1746068	0,3302085	I5g	0,5394468	0,6402072	0,2070981	0,3597928
I2j	0,5038562	0,6117255	0,2355608	0,3882745	I5h	0,5047714	0,6141208	0,2352732	0,3858792
I2k	0,5612784	0,6626233	0,1824062	0,3373767					

General / Surgical Errors	Severity*Preventability				General / Surgical Errors	Severity*Preventability			
	a	b	c	d		a	b	c	d
C1di	0,5522035	0,6545302	0,1905857	0,3454698	C4ad	0,5578032	0,6628746	0,1797429	0,3371254
C1ik	0,5523185	0,6578916	0,1857658	0,3421084	C4kk	0,5690868	0,6737697	0,1694434	0,3262303
C1ac	0,5603943	0,6631087	0,1813491	0,3368913	C4gc	0,5396639	0,6442518	0,1994108	0,3557482
C1tr	0,5350993	0,639924	0,2053602	0,360076	C4hd	0,5374446	0,6450646	0,2009824	0,3549354
C1gd	0,5238851	0,6284945	0,2174423	0,3715055	C5kd	0,5424396	0,6448974	0,2008255	0,3551026
C1oi	0,5364861	0,639636	0,2060752	0,360364	C5et	0,5190988	0,6237139	0,2244926	0,3762861
C1mk	0,5492868	0,6510055	0,1960086	0,3489945	C5kc	0,5401886	0,6429168	0,2024592	0,3570832
C1tk	0,5095276	0,6166482	0,2313792	0,3833518	C5ka	0,5397948	0,6432706	0,2022315	0,3567294
C1oa	0,491201	0,600975	0,2463158	0,399025	C5sk	0,5467708	0,6531656	0,1906722	0,3468344
C1ok	0,4964209	0,6064177	0,2416613	0,3935823	C5cp	0,5498794	0,6534781	0,1903972	0,3465219
C2kd	0,5424396	0,6448974	0,2008255	0,3551026	C5ks	0,536498	0,6415059	0,2026968	0,3584941
C2te	0,5219024	0,6249634	0,2212709	0,3750366	C5ko	0,5294384	0,6340263	0,2120431	0,3659737
C2ta	0,5270904	0,6303888	0,2154426	0,3696112	C5vp	0,5245138	0,6290769	0,2164228	0,3709231
C2ti	0,5139653	0,6189667	0,228899	0,3810333	C6ku	0,5511296	0,6574937	0,186597	0,3425063
C3at	0,5719104	0,6753804	0,1679791	0,3246196	C6pf	0,5216831	0,6266619	0,2196261	0,3733381
C3ak	0,5554491	0,6600888	0,1838363	0,3399112	C7gi	0,5424396	0,6448974	0,2008255	0,3551026
C3ck	0,5409259	0,6450962	0,1980194	0,3549038	C7ta	0,5413338	0,647134	0,1971462	0,352866
C3gk	0,574953	0,6784321	0,1636407	0,3215679	C7pe	0,5192344	0,6260018	0,2195038	0,3739982
C3pk	0,5655469	0,6686666	0,1758662	0,3313334	C7cg	0,5260346	0,6282941	0,218445	0,3717059
C3sn	0,5551583	0,6585731	0,1852991	0,3414269	C7ag	0,5322263	0,6355873	0,2099915	0,3644127
C3tg	0,5718323	0,6752292	0,1685385	0,3247708	C7gy	0,5166406	0,6206508	0,2262642	0,3793492
C4kd	0,5424396	0,6448974	0,2008255	0,3551026	C8gb	0,5113041	0,6157941	0,2323492	0,3842059
C4ok	0,4964209	0,6064177	0,2416613	0,3935823	C8kd	0,5296841	0,6334807	0,2131385	0,3665193
C4ik	0,5523185	0,6578916	0,1857658	0,3421084	C8ta	0,5270904	0,6303888	0,2154426	0,3696112
C4po	0,5499966	0,6552229	0,1887317	0,3447771	C8ts	0,5219024	0,6249634	0,2212709	0,3750366

Patient Based Errors	Severity*Preventability				Patient Based Errors	Severity*Preventability			
	a	b	c	d		a	b	c	d
BYHa	0,535191	0,639464	0,2026649	0,360536	BTHj	0,532403	0,6415201	0,2067254	0,3584799
BYHb	0,5495419	0,6556328	0,1881567	0,3443672	BTHk	0,527576	0,6377011	0,2092293	0,3622989
BYHc	0,576095	0,6787134	0,1654225	0,3212866	BTHl	0,5519818	0,6600025	0,1873386	0,3399975
BYHd	0,5606408	0,6641688	0,1802283	0,3358312	BTHm	0,4784751	0,5868647	0,2624321	0,4131353
BYHe	0,5197868	0,6309557	0,2107435	0,3690443	BTHn	0,5350116	0,6401664	0,2026268	0,3598336
BYHf	0,5289764	0,6392279	0,2026796	0,3607721	BTHo	0,5576978	0,6629214	0,1808278	0,3370786
BYHg	0,4975082	0,6061073	0,2408285	0,3938927	BTHp	0,5052263	0,6081172	0,2407152	0,3918828
BYHh	0,5295764	0,6318827	0,2141678	0,3681173	BTHq	0,5250099	0,6322141	0,2153113	0,3677859
BYHi	0,5477601	0,6517481	0,1942351	0,3482519	BTHr	0,5519413	0,6573319	0,1871814	0,3426681

BYHj	0,5729115	0,6755716	0,16945	0,3244284	BTHs	0,5466567	0,6486082	0,1981568	0,3513918
BYHk	0,5650982	0,6688728	0,1782971	0,3311272	BTHt	0,5422236	0,6451729	0,2009216	0,3548271
BYHl	0,5394929	0,6440632	0,2022758	0,3559368	BTHu	0,5433438	0,6460655	0,2010362	0,3539345
BYHm	0,5400145	0,6436424	0,2012132	0,3563576	BTHv	0,5422236	0,6451729	0,2009216	0,3548271
BYHn	0,5562119	0,6611017	0,1842249	0,3388983	HRHa	0,5342482	0,6439819	0,2065798	0,3560181
BYHo	0,5130868	0,6210678	0,2235847	0,3789322	HRHb	0,5389243	0,6399562	0,2066917	0,3600438
BYHp	0,5447138	0,6516728	0,1926282	0,3483272	HRHc	0,5704878	0,672229	0,1713745	0,327771
CSHa	0,5286688	0,6348598	0,2119331	0,3651402	HRHd	0,535045	0,6361349	0,2100364	0,3638651
CSHb	0,537637	0,6432972	0,2024039	0,3567028	HRHe	0,537351	0,6386297	0,2067433	0,3613703
CSHc	0,5588676	0,6616973	0,1844957	0,3383027	HRHf	0,5197335	0,6223517	0,2239396	0,3776483
CSHd	0,5438959	0,6477167	0,1986062	0,3522833	HRHg	0,5300499	0,630936	0,2158462	0,369064
CSHe	0,54048	0,6432992	0,2028823	0,3567008	HRHh	0,5218031	0,6221781	0,2266872	0,3778219
CSHf	0,5543324	0,6576354	0,1880861	0,3423646	HRHi	0,5059684	0,6114723	0,2363903	0,3885277
CSHg	0,4816051	0,5937769	0,2564904	0,4062231	HRHj	0,530084	0,6324845	0,2129327	0,3675155
CSHh	0,5500645	0,6525646	0,1923845	0,3474354	HRHk	0,4999776	0,6029129	0,244494	0,3970871
CSHi	0,4929842	0,6042138	0,2432427	0,3957862	HTHl	0,5052263	0,6081172	0,2407152	0,3918828
CSHj	0,5311739	0,6370493	0,2081024	0,3629507	HTHm	0,4995832	0,6085837	0,2374866	0,3914163
CSHk	0,5005011	0,6098725	0,236436	0,3901275	HTHn	0,5059684	0,6114723	0,2363903	0,3885277
CSHl	0,5202497	0,6269803	0,2193383	0,3730197	KTSa	0,5654686	0,6708607	0,1705315	0,3291393
CSHm	0,500316	0,6088991	0,2390619	0,3911009	KTSb	0,5153837	0,620361	0,2277419	0,379639
CSHn	0,5704878	0,672229	0,1713745	0,327771	KTSc	0,5524546	0,6556053	0,1884321	0,3443947
TKHa	0,5654686	0,6708607	0,1705315	0,3291393	KTSd	0,5525377	0,6553588	0,1911273	0,3446412
TKHb	0,5617492	0,6679714	0,1756119	0,3320286	KTSe	0,5174779	0,6238237	0,2226537	0,3761763
TKHc	0,5476582	0,6545472	0,1886391	0,3454528	KTSf	0,5373609	0,640853	0,2055373	0,359147
TKHd	0,525992	0,6286742	0,2177749	0,3713258	KTSg	0,5185627	0,62094	0,2263149	0,37906
TKHe	0,5202675	0,6218341	0,2265948	0,3781659	NIHa	0,5355674	0,6363852	0,2106309	0,3636148
TKHf	0,5263435	0,6291331	0,2175396	0,3708669	NIHb	0,5552127	0,6590018	0,1844808	0,3409982
TKHg	0,5468075	0,6495308	0,1973934	0,3504692	NIHc	0,5493724	0,6499677	0,1980393	0,3500323
ILHa	0,5181745	0,6186789	0,2298335	0,3813211	NIHd	0,5497091	0,6505477	0,1968205	0,3494523
ILHb	0,535351	0,6360805	0,2113352	0,3639195	NIHe	0,5382636	0,6390755	0,2083114	0,3609245
ILHc	0,4995832	0,6085837	0,2374866	0,3914163	NIHf	0,5677796	0,6720284	0,1710733	0,3279716
BTHa	0,5421513	0,6458042	0,1988644	0,3541958	NIHg	0,5323325	0,6329584	0,2150608	0,3670416
BTHb	0,5474952	0,6507648	0,1938176	0,3492352	NIHh	0,5377388	0,6385634	0,2086425	0,3614366
BTHc	0,5273941	0,6300765	0,2152496	0,3699235	NIHi	0,5462034	0,6464065	0,202952	0,3535935
BTHd	0,5425953	0,6447857	0,2003532	0,3552143	NIHj	0,5449654	0,6454657	0,2027886	0,3545343
BTHe	0,5507914	0,6538362	0,1912994	0,3461638	NIHk	0,541817	0,6419141	0,2077815	0,3580859
BTHf	0,5439304	0,6464198	0,2000292	0,3535802	NIHl	0,5497753	0,6504891	0,1968336	0,3495109
BTHg	0,5455138	0,6481656	0,1968288	0,3518344	NIHm	0,5505294	0,6513923	0,195219	0,3486077
BTHh	0,5704878	0,672229	0,1713745	0,327771	NIHn	0,5399625	0,6406943	0,2070616	0,3593057
BTHi	0,5270904	0,6303888	0,2154426	0,3696112					

Appendix 4

Number of Reported Events during 2017

System Code	Hospital Code	1st 6 Month	2nd 6 Month	System Code	Hospital Code	1st 6 Month	2nd 6 Month	System Code	Hospital Code	1st 6 Month	2nd 6 Month
PRL01	L01	2	2	I1d	I1d	0	0	C1ok	C1ok	2	1
PRL02	L02	88	7	I1e	I1e	0	0	C2ta	C2ta	1	0
PRL04	L04	2	1	I1f	I1f	0	1	C4ad	C4ad	1	0
PRL05	L05	4	3	I1g	I1g	3	6	C4hd	C4hd	0	1
PRL06	L06	0	1	I1h	I1h	0	0	C5ks	C5ks	1	0
PRL07	L07	7	11	I1i	I1i	0	1	C7cg	C7cg	0	2
PRL08	L08	1	0	I1j	I1j	1	0	C8gb	C8gb	0	2
PRL10	L10	9	22	I2a	I2a	1	1	BTHg	1	38	37
PRL13	L13	4	23	I2b	I2b	10	4	TKHa	2	1	5
PRL15	L15	5	6	I2c	I2c	0	1	TKHg	3	1	3
PRL16	L16	0	7	I2d	I2d	2	1	BTHf	4	4	6
PRL18	L18	0	1	I2j	I2j	1	0	BTHa	5	5	5
PRL21	L21	2	5	I2n	I2n	1	0	BTHf	6	3	1
PRL23	L23	1	0	I3b	I3b	1	0	BTHb	7	0	0
PRL24	L24	3	8	I3c	I3c	3	5	NIHm	8	1	3
PRL25	L25	1	1	I4c	I4c	1	2	KTSb	11	0	3
PRL26	L26	1	0	I4d	I4d	0	2	CSHm	14	0	1
PRL27	L27	1	0	I4e	I4e	1	3	BTHu	15	8	5
PRL29	L29	1	0	I4f	I4f	2	0	HRHi	18	0	1
ANL42	L42	0	7	I4h	I4h	0	2	KTSb	19	8	13
ANL43	L43	0	0	I4k	I4k	0	9	BTHc	20	0	0
ANL44	L44	8	23	I4n	I4n	0	1	ILHa	21	0	14
ANL52	L52	1	0	I4j	I6a	11	18		22	110	119
POL55	L55	0	3	I4i	I6b	3	4	BYHk	1	0	1
POL56	L56	0	0	I3e	I6c	0	1		9	3	10
POL57	L57	2	0	I5b	I6e	1	1	BTHn	4	0	1
POL58	L58	1	0		I6h	36	125	CSHc	1	3	1
	L59	16	29	C1di	C1di	1	0	CSHd	3	3	0
I0f	I0f	0	1	C1ik	C1ik	1	2	HRHd	6	1	1
I0k	I0k	2	1	C1tr	C1tr	1	1		7	3	8
I0l	I0l	3	1	C1gd	C1gd	3	1	CSHe	2	0	1
I1a	I1a	0	2	C1mk	C1mk	0	1	BYHn	3	1	0
I1b	I1b	19	4	C1tk	C1tk	0	1	CSHe	4	0	3
I1c	I1c	0	0	C1oa	C1oa	4	1		5	6	14

Appendix 5

	Index Score		Index Score
Other (C9-22)	0,65869	Unevaluated blood sugar control necessity	0,76495
Other (L59)	0,69238	The operation area has not been shaved	0,76531
Other (16h)	0,69238	Failure to follow instructions	0,76536
Other (C9-5)	0,69238	Wrong loading of drugs	0,76540
Missed/wrong information in test request	0,69664	Distribution of drugs at the wrong time	0,76555
Drug inconsistency	0,71344	Incorrect evaluation of the result	0,76558
No authentication	0,71674	No drug registration on the patient	0,76588
Improper insulation measures	0,71721	Expired drugs	0,76615
Late processing	0,71755	Results that are not given in time	0,76640
Incorrect sample identification	0,71951	Exceeding the determined maximum transfer duration of the sample	0,76646
Preparation of wrong drug	0,71992	Presence of medication near the patient	0,76699
Inappropriate taken sample	0,72191	Do not deliver the patient to the health worker	0,76714
Wrong drug selection in electronic system	0,72219	Do not deliver the patient to the health worker	0,76714
Transfusion reaction	0,72440	Erroneous dosing	0,76759
Nonconformity of external quality control studies	0,72782	Not confirming removal of make-up, prosthesis and valuable items	0,76782
Incorrect sample container/tube	0,73614	Transferring wrong drug from pharmacy	0,76830
Other (C9-9)	0,74197	Inappropriate stored sample	0,76878
Other (C9-7)	0,74197	Acceptance of the samples that should be rejected	0,76985
Wrong dosage (high)	0,75476	Missing sample	0,77013
Wrong patient	0,75478	Not barcoded sample	0,77051
Absence of arm band	0,75864	Unsent sample in fixative	0,77142
Device not working	0,75999	Incorrect labelling of drugs	0,77223
Wrong dosage (low)	0,76015	Incorrect labelling of prepared drugs	0,77223
Unevaluated allergy status	0,76028	Inappropriate transfer conditions	0,77289
Lately reported panic value	0,76044	Lack of communication	0,77296
Damage to the sterile material package	0,76049	Wrong test request	0,77303
Not controlling marking of the operation area / side	0,76143	Misinterpretation of doctor's demand	0,77351
Non-Marking of operation area / side	0,76153	Not controlling the receive of patient's consent	0,77390
Infection-induced event	0,76187	Unrecorded sample	0,77416
False information in the arm band	0,76266	Not receiving patient's consent	0,77513
Undone planned action	0,76328	Undelivered sample in the laboratory	0,77545
Wrong processing	0,76328	Wrong record	0,77594
Device malfunction	0,76331	Loss of drugs	0,77740
Mixing of samples	0,76354		

	Index Score		Index Score
Unorganized pathology request form	1,00000	Drug application not recorded	1,00000
Sampling from the wrong patient	1,00000	Non-removal of wastes after drug application	1,00000
Recollected sample	1,00000	No observations after drug administration	1,00000
Empty sample container/tube	1,00000	Adverse effect (management not defined)	1,00000
Samplig with expired tubes	1,00000	Adverse effect (Notification)	1,00000
Cancellation of the record because a sample could not be obtained from the patient	1,00000	Not observed drug-drug, drug-food interaction	1,00000
Insufficient sample	1,00000	Original packaging of the returned medicine is broken	1,00000
Sample with hemolysis	1,00000	Not loading the drugs on time	1,00000
Clotted sample	1,00000	Drug with no expiration date	1,00000
Lipemic sample	1,00000	Prescriptions not placed in patient file	1,00000
Icteric sample	1,00000	Boxes that should be placed in the patient file is not placed	1,00000
Time of sampling is not saved	1,00000	Pre-op fasting requirement not confirmed	1,00000
Automation failure	1,00000	Skipping pre-operative special procedure (enema application etc.)	1,00000
Determination of expired kit	1,00000	Failure to control supply of supplies and blood / blood products for surgery	1,00000
Determination of expired material	1,00000	Do not check that examination and surveys are near the patient	1,00000
Requested material/kit is not arrived	1,00000	Unverified Patient ID, location of operation and surgical procedure	1,00000
Arrived material/kit is wrong	1,00000	Health worker does not accompany patient transfer	1,00000
Inappropriate material transfer conditions	1,00000	Failure to transmit information about the operation during delivery	1,00000
Inappropriate stored material	1,00000	Failure of cleaning of operation room and surgical table	1,00000
Inappropriate temperature of laboratory	1,00000	Not controlling of anesthesia devices and equipment	1,00000
Undone device maintenance	1,00000	Equipment malfunction due to lack of calibration / maintenance	1,00000
Inappropriate preparation of medium	1,00000	Do not check that the outlets are connected to uninterruptible power supply	1,00000
Automation failure	1,00000	Not performing particle counting / checking	1,00000
Equipment failure	1,00000	Inadequate control of room temperature and humidity	1,00000
Equipment strawing failure	1,00000	Not controlling the medical gas system	1,00000
Insufficient homogenization of the sample	1,00000	Unverified Patient ID, location of operation and surgical procedure	1,00000
Failure to follow test procedures	1,00000	Not controlling the receive of patient's consent	1,00000
Seeding failure	1,00000	Not controlling marking of the operation area / side	1,00000
Working with improper quality control outputs	1,00000	Pulse oximeter device not on patient and not controlled	1,00000
Not working wiht internal quality control	1,00000	Not evaluating the necessity of blood transfusion	1,00000

Inappropriate incubation temperature	1,00000	Not controlling the display devices that may be needed	1,00000
Inappropriate incubation period	1,00000	Unresolved anesthesia risks	1,00000
Inappropriate pigmentation technique	1,00000	Unverified Patient ID, location of operation and surgical procedure	1,00000
Improper dilution	1,00000	Team members do not identify themselves	1,00000
Using improper solution	1,00000	Critical events that can occur due to surgery are not evaluated	1,00000
Incorrect technical approval	1,00000	Unevaluated critical event that can occur due to anesthesia	1,00000
Wrong record	1,00000	Do not check that the materials are ready and sterile	1,00000
Automation failure	1,00000	Not applying the required surgical prophylaxis	1,00000
Incorrectly entered report results	1,00000	Unquestioning of the use of anticoagulants	1,00000
Incorrect report	1,00000	Do not apply the required DVT prophylaxis	1,00000
Unsaved patient reports	1,00000	No patient compliance check when blood / blood product use is required	1,00000
Rejection of the sample based on the rejection criteria	1,00000	No appropriate labeling of the sample when frozen is required	1,00000
Inappropriate temperature and humidity	1,00000	Unverified Patient ID, location of operation and surgical procedure	1,00000
Violation of FIFO rule	1,00000	Uncontrolled instrument, sponge, compress and needle counts that are used	1,00000
Light exposure	1,00000	Not properly labelled receipt samples	1,00000
Confusion in selection because of the similarity in writing, reading or appearance of the drugs	1,00000	Unrecognized possible surgical critical care requirements	1,00000
Pediatric doses are on the same shelf with other drugs	1,00000	Potential anesthesia critical maintenance requirements not assessed	1,00000
Failure in controlling of critical stock level	1,00000	Not specifying the part of the post-op patient to be transferred	1,00000
Faulty expiration date and critical stock level warning system	1,00000	Failure to transmit surgical critical care requirements to healthcare personnel who receives the patient	1,00000
Undefined high-risk drugs	1,00000	Patient identity, surgical procedure and the part of the patient to be transferred are not verified	1,00000
Undefined psychotropic and narcotic drugs	1,00000	Health worker does not accompany patient transfer	1,00000
Stolen drugs	1,00000	Op / post-op complication	1,00000
Wrong drug demand	1,00000	Wrong diagnosis	1,00000
Choosing wrong treatment	1,00000	Unexpected death / loss of function	1,00000
Writing contraindicated drugs	1,00000	Blood transfusion failure	1,00000
Using abbreviation in drug name	1,00000	Lost sample	1,00000
Illegible handwriting	1,00000	Burn	1,00000
Misunderstanding of verbal demand	1,00000	Non-confidential patient information	1,00000
Unwritten verbal demand	1,00000	Wrong treatment	1,00000
Incorrect packaging of drugs	1,00000	Patient injury / death during restriction	1,00000
Undefined medicines that brought by the patient	1,00000	Run away of patient	1,00000
Unimplemented hand hygiene	1,00000	Perinatal death / loss of function	1,00000

Drug incompatibility	1,00000	Error in patient informing and approvals process	1,00000
Preparing the medicine with the wrong technique	1,00000	Fire-Explosion	1,00000
Confusion in selection because of the similarity in writing, reading or appearance of the drugs	1,00000	Water-Gas leakage	1,00000
Drug application without doctor request	1,00000	Insect-Animal events	1,00000
Unauthorized drug application	1,00000	Staying Locked-Closed	1,00000
Impaired drug application	1,00000	Exposure to radiation	1,00000
Inaccurate information about the use of medicine	1,00000	Exposure to infected waste	1,00000
Not informing the patient about the use of the medicine	1,00000	Contamination of chemicals	1,00000
Prepared medicines sent to the wrong patient	1,00000	Electrical eclipse exposure	1,00000
Wrong delivery of medicines	1,00000	Suicide	1,00000
Do not send drugs to patients / department on time	1,00000	Selfdestruction / Self-harm	1,00000
Unimplemented hand hygiene	1,00000	Harassment-abuse-rape	1,00000
Failure to comply with sterilization / disinfection rules	1,00000	Child / infant loss / abduction	1,00000
Wrong drug	1,00000	Fighting - Beating	1,00000
Wrong pharmaceutical form	1,00000	Extortion - Theft	1,00000
Wrong time	1,00000	Mixed newborn	1,00000
Wrong methodology	1,00000	Patient abduction	1,00000
Applying incompatible drugs at the same time	1,00000	Non-existent device	1,00000
Skipping a dosage	1,00000	Electricity leakage in the device	1,00000
Repeated drug administration	1,00000	Device-related burn-injury	1,00000
Incorrect application period (Injection)	1,00000	Contaminate material	1,00000
Incorrect application period (Infusion)	1,00000	No medical supplies	1,00000
No hand hygiene after drug application	1,00000	Material shortage in sets	1,00000

Appendix 6

Rank	Error Explanation	Score	Rank	Error Explanation	Score
1	Other (C9-22)	0,86462	169	Incorrect evaluation of the result	0,65424
2	Other (C9-5)	0,86462	170	Not evaluated nutritional status of the patient	0,65394
3	Other (C9-7)	0,86462	171	Preparation of wrong drug	0,65383
4	Other (C9-9)	0,86462	172	Failure to follow instructions	0,65379
5	Other (Lab)	0,80619	173	The patient does not follow the care / treatment guidelines in the hospitalization process	0,65379
6	Other (MED)	0,80619	174	Missing/ Lack of information about the care, diagnosis method or treatment	0,65352
7	Rejection of the sample based on the rejection criteria	0,80619	175	Failure to provide training about the emergency and disaster management	0,65336
8	Wrong dosage (high)	0,71103	176	Misunderstanding of verbal demand	0,65267
9	Wrong patient	0,71075	177	Inappropriate incubation temperature	0,65264
10	Wrong drug	0,70911	178	Distribution of drugs at the wrong time	0,65258
11	Impaired drug application	0,70442	179	Potential anesthesia critical maintenance requirements not assessed	0,65251
12	Patient fall/injured due to the escalator malfunction	0,70186	180	Unsaved patient reports	0,65239
13	Do not check that the outlets are connected to uninterruptible power supply	0,70184	181	Late intervention in pink code condition	0,65207
14	Electrical eclipse exposure	0,69804	182	Drug with no expiration date	0,65186
15	Electricity leakage in the device	0,69804	183	Expired drugs	0,65186
16	Injured patients due to the electric leakage	0,69804	184	Boxes that should be placed in the patient file is not placed	0,65085
17	Failure of cleaning of operation room and surgical table	0,69803	185	Drug application not recorded	0,65085
18	Not controlling the medical gas system	0,69776	186	No drug registration on the patient	0,65085
19	Not evaluating the necessity of blood transfusion	0,69583	187	Prescriptions not placed in patient file	0,65085
20	Patient Fall	0,69499	188	Injured patient due to the movement restriction equipment	0,65033
21	Patient Fall	0,69499	189	Patient injury / death during restriction	0,65033
22	Patient Falls	0,69499	190	Adverse effect (management not defined)	0,65018
23	Food poisoning	0,69404	191	Unquestioning of the use of anticoagulants	0,65017
24	Absence of arm band	0,69281	192	Inadequate nutrition of the patient during treatment	0,64988
25	Incorrect identification of patients	0,69281	193	No hand hygiene after drug application	0,64977
26	Not confirmed patient identity	0,69281	194	Unimplemented hand hygiene	0,64977
27	Failure to comply with sterilization / disinfection rules	0,69237	195	Unimplemented hand hygiene	0,64977

28	Confusion in selection because of the similarity in writing, reading or appearance of the drugs	0,69212	196	Patient identity, surgical procedure and the part of the patient to be transferred are not verified	0,64969
29	Confusion in selection because of the similarity in writing, reading or appearance of the drugs	0,69212	197	Exceeding the determined maximum transfer duration of the sample	0,64966
30	Prepared medicines sent to the wrong patient	0,69084	198	Providing incomplete / misleading information about the patient's health histories	0,64940
31	Not performing particle counting / checking	0,69023	199	Working with improper quality control outputs	0,64908
32	Burn	0,68949	200	No observations after drug administration	0,64868
33	Fire-Explosion	0,68949	201	Lack of elderly or disabled patient instructions	0,64858
34	Injured patients due to the fire /explosion	0,68949	202	Results that are not given in time	0,64840
35	Wrong pharmaceutical form	0,68885	203	Use of medication / nutrition / food supplement without the healthcare staff's knowledge	0,64784
36	Delivering someone else's receipt to the patient	0,68863	204	Late detection of hyperbilirubinemia in the newborn	0,64678
37	Patient fall/injured due to the slippery floors	0,68504	205	Presence of medication near the patient	0,64677
38	Pre-op fasting requirement not confirmed	0,68411	206	Undefined psychotropic and narcotic drugs	0,64660
39	Repeated drug administration	0,68390	207	Patient care plan not determined according to patient needs	0,64660
40	Drug application without doctor request	0,68388	208	Perinatal death / loss of function	0,64660
41	Unevaluated allergy status	0,68354	209	Wrong treatment	0,64660
42	Application with medical device filled with calibration period	0,68322	210	Do not deliver the patient to the health worker	0,64659
43	Lately reported panic value	0,68206	211	Do not deliver the patient to the health worker	0,64659
44	Device not working	0,68200	212	Unsuitable patient delivery	0,64659
45	Untimely repaired / replaced defective equipment	0,68200	213	Do not send drugs to patients / department on time	0,64631
46	Applying incompatible drugs at the same time	0,68195	214	Not loading the drugs on time	0,64631
47	Drug incompatibility	0,68195	215	Skipping a dosage	0,64615
48	Drug inconsistency	0,68195	216	Incorrect technical approval	0,64561
49	Wrong dosage (low)	0,68150	217	Equipment strapping failure	0,64551
50	Contamination of chemicals	0,68084	218	The absence of a disaster and emergency plan	0,64540
51	Contaminate material	0,68084	219	Unorganized pathology request form	0,64527
52	Damage to the sterile material package	0,68084	220	Missing / Wrong evaluation / consultations notes	0,64514
53	Exposure to hazardous waste /material except for diagnosis / treatment purposes	0,68084	221	Writing contraindicated drugs	0,64487

54	Exposure to infected waste	0,68084	222	Do not apply the required DVT prophylaxis	0,64474
55	Exposure to radiation	0,68084	223	Incorrect handling of medical records about the applied care or treatment	0,64472
56	Not controlling of anesthesia devices and equipment	0,68018	224	Inappropriate taken sample	0,64468
57	Unquestioned food allergy story of the patient	0,67937	225	Unrecognized possible surgical critical care requirements	0,64437
58	Incorrect report	0,67892	226	Sampling from the wrong patient	0,64405
59	Inadequate control of room temperature and humidity	0,67891	227	Not confirming removal of make-up, prosthesis and valuable items	0,64395
60	Late intervention in red code condition	0,67794	228	Erroneous dosing	0,64386
61	Not controlling marking of the operation area / side	0,67744	229	Icteric sample	0,64206
62	Not controlling marking of the operation area / side	0,67744	230	Wrong drug selection in electronic system	0,64194
63	Device-related burn-injury	0,67738	231	Inappropriate stored material	0,64171
64	Injured patient due to the device failure	0,67738	232	No appropriate labeling of the sample when frozen is required	0,64165
65	Late detection of hypoglycemia in the newborn	0,67663	233	Loss of patient information data because of the safety problem in information network	0,64135
66	No patient compliance check when blood / blood product use is required	0,67658	234	Inappropriate incubation period	0,64064
67	Not checking product information (Blood group, Cross-match, SKT, Tests etc.)	0,67560	235	Health worker does not accompany patient transfer	0,64045
68	Incorrect application period (Infusion)	0,67560	236	Health worker does not accompany patient transfer	0,64045
69	Product label information is incorrect	0,67477	237	Not properly labelled receipt samples	0,64045
70	Patient fall/injured due to the elevator malfunction	0,67466	238	Inappropriate temperature of laboratory	0,63999
71	Pulse oximeter device not on patient and not controlled	0,67446	239	Transferring wrong drug from pharmacy	0,63965
72	Non-Marking of operation area / side	0,67438	240	Requested material/kit is not arrived	0,63882
73	Unauthorized drug application	0,67428	241	Inappropriate stored sample	0,63855
74	Non-removal of wastes after drug application	0,67386	242	Team members do not identify themselves	0,63796
75	Undefined high-risk drugs	0,67342	243	Incorrect transfer of blood product	0,63789
76	No asepsis / sterilization / isolation requirements for care	0,67334	244	Changing the bed without the healthcare provider's knowledge	0,63765
77	Mixed newborn	0,67331	245	The patient does not fulfill preoperative requirements	0,63761
78	Wrong delivery of the newborn	0,67331	246	Illegible evaluation / consultations notes	0,63690
79	Not applying the required surgical prophylaxis	0,67309	247	Insufficient sample	0,63617
80	Incorrectly entered report results	0,67271	248	Failure to observe patients properly before and after the procedure	0,63590

81	Untimely interfere to the sentinel event notifications	0,67215	249	Arrived material/kit is wrong	0,63582
82	Do not check that the materials are ready and sterile	0,67175	250	Undone device maintenance	0,63559
83	Infection-induced event	0,67095	251	Not working with internal quality control	0,63544
84	Maintenance-induced TPN catheter infection	0,67095	252	Not specifying the part of the post-op patient to be transferred	0,63506
85	Incorrect application period (Injection)	0,67054	253	Absence of noise control in the intensive care unit	0,63463
86	Medical gas contamination or incorrect gas mixture	0,67042	254	Wrong drug demand	0,63411
87	Failure to control supply of supplies and blood / blood products for surgery	0,67010	255	Blood transfusion failure	0,63407
88	Complication developed in the patient due to consultation delay	0,66995	256	Lack of records of transfusion request	0,63407
89	Op / post-op complication	0,66995	257	Transfusion reaction	0,63407
90	Giving the wrong food to the patient	0,66980	258	Error in patient informing and approvals process	0,63371
91	PN suspension given to the wrong patient	0,66979	259	Uninformed patient about the care, diagnosis method or treatment	0,63371
92	Basic facility resource related backup systems didn't started in time	0,66973	260	Determination of expired kit	0,63327
93	Improper nutritional support or diet choice for the patient	0,66905	261	Equipment failure	0,63301
94	False information in the arm band	0,66811	262	Undefined medicines that brought by the patient	0,63292
95	Incorrect record of patient basic information	0,66811	263	Failure to transmit information about the operation during delivery	0,63255
96	Pediatric doses are on the same shelf with other drugs	0,66787	264	Acceptance of the samples that should be rejected	0,63246
97	Late detection of premature retinopathy in the newborn	0,66738	265	Sample with hemolysis	0,63223
98	Confirmation of patient identity before treatment / care	0,66712	266	Failure to follow test procedures	0,63154
99	No authentication	0,66712	267	Lipemic sample	0,63150
100	Device malfunction	0,66583	268	Insufficient homogenization of the sample	0,63104
101	Untimely made device calibration and /or tests	0,66583	269	Missing sample	0,63086
102	Mixing of samples	0,66547	270	Seeding failure	0,62998
103	Uncontrolled instrument, sponge, compress and needle counts that are used	0,66502	271	Not barcoded sample	0,62983
104	Incorrect preparation of PN suspension	0,66481	272	Do not check that examination and surveys are near the patient	0,62910
105	Misassignment of assay and test results	0,66481	273	Failure to transmit surgical critical care requirements to healthcare personnel who receives the patient	0,62908
106	Undone planned action	0,66481	274	Using improper solution	0,62731

107	Wrong diagnosis	0,66481	275	Unsent sample in fixative	0,62566
108	Wrong processing	0,66481	276	Original packaging of the returned medicine is broken	0,62506
109	Complication developed in the patient due to maintenance / treatment delay	0,66418	277	Missed/wrong information in test request	0,62449
110	Late processing	0,66418	278	Departure from the health facility without the knowledge of the hospital's health personnel	0,62390
111	Failure to provide the necessary protective equipment to the patient during medical imaging	0,66415	279	Run away of patient	0,62390
112	Improper insulation measures	0,66415	280	The patient does not follow post-discharge care / treatment guidelines	0,62390
113	Incorrectly protected PN suspension	0,66395	281	Incorrect labelling of drugs	0,62344
114	Preparing the medicine with the wrong technique	0,66370	282	Incorrect labelling of prepared drugs	0,62344
115	Equipment malfunction due to lack of calibration / maintenance	0,66362	283	Light exposure	0,62335
116	Inaccurate information about the use of medicine	0,66359	284	Clotted sample	0,62270
117	No evaluation of the patient in terms of nutrition	0,66343	285	Inappropriate material transfer conditions	0,62268
118	Giving the wrong blood / blood product to the patient	0,66333	286	Improper dilution	0,62252
119	Not monitoring of complications developing after care or treatment	0,66333	287	Not evaluated patient complaints and feedbacks	0,62102
120	Unverified Patient ID, location of operation and surgical procedure	0,66330	288	Formation of 3rd level and higher pressure ulcer in patient in hospitalization period	0,62085
121	Unverified Patient ID, location of operation and surgical procedure	0,66330	289	Formation of 3rd level pressure after the discharge	0,62085
122	Unverified Patient ID, location of operation and surgical procedure	0,66330	290	Automation failure	0,62071
123	Unverified Patient ID, location of operation and surgical procedure	0,66330	291	Automation failure	0,62071
124	Lost sample	0,66275	292	Automation failure	0,62071
125	Not controlling the display devices that may be needed	0,66236	293	Nonconformity of external quality control studies	0,62012
126	Flood / Sewage flood	0,66170	294	Non-confidential patient information	0,61980
127	Unresolved anesthesia risks	0,66155	295	Stolen patient information data because of the safety problem in information network	0,61980
128	Contamination of water resources	0,66144	296	Wrong test request	0,61980
129	Insect-Animal events	0,66144	297	Care and treatment after hospitalization	0,61976
130	Water-Gas leakage	0,66144	298	The patient does not come to control after discharge	0,61976
131	Lack of care, diagnosis and treatment process related equipment	0,66124	299	Wrong delivery of medicines	0,61968
132	Material shortage in sets	0,66124	300	Incorrect packaging of drugs	0,61918
133	No medical supplies	0,66124	301	Faulty expiration date and critical stock level warning system	0,61876

134	Non-existent device	0,66124	302	Inappropriate pigmentation technique	0,61844
135	Unevaluated critical event that can occur due to anesthesia	0,66116	303	Determination of expired material	0,61800
136	Critical events that can occur due to surgery are not evaluated	0,66106	304	Inappropriate transfer conditions	0,61784
137	Unprovided asepsis conditions due to the lack of infrastructure / equipment	0,66035	305	Lack of communication	0,61778
138	Incorrect application of PN suspension	0,65970	306	Unwritten verbal demand	0,61778
139	Unevaluated blood sugar control necessity	0,65896	307	Missing /Not found patient instruction marks	0,61690
140	Not informing the patient about nutrition while being discharged	0,65863	308	Not controlling the receive of patient's consent	0,61643
141	Suicide	0,65835	309	Not controlling the receive of patient's consent	0,61643
142	Suicide attempt resulting in serious injury or death	0,65835	310	Misinterpretation of doctor's demand	0,61596
143	Not observed drug-drug, drug-food interaction	0,65819	311	The refusal of compulsory education by the patient or accompanying persons	0,61532
144	Incorrect application of blood product	0,65819	312	Time of sampling is not saved	0,61520
145	Selfdestruction / Self-harm	0,65799	313	Illegible handwriting	0,61455
146	The patient's health condition causes harm to other patients	0,65799	314	Unrecorded sample	0,61363
147	Child / infant loss / abduction	0,65777	315	Not evaluated internal safety report notifications	0,61362
148	Extortion - Theft	0,65777	316	Sampling with expired tubes	0,61300
149	Fighting - Beating	0,65777	317	Not receiving patient's consent	0,61055
150	Harassment-abuse-rape	0,65777	318	Inappropriate temperature and humidity	0,60962
151	Patient abduction	0,65777	319	Inappropriate preparation of medium	0,60942
152	Patient safety not provided	0,65777	320	Undelivered sample in the laboratory	0,60695
153	Patient stuck in the elevator due to the malfunction	0,65748	321	Wrong record	0,60659
154	Staying Locked-Closed	0,65748	322	Wrong record	0,60659
155	Skipping pre-operative special procedure (enema application etc.)	0,65712	323	Failure in controlling of critical stock level	0,60556
156	The operation area has not been shaved	0,65695	324	Using abbreviation in drug name	0,60151
157	Food brought to the patient from outside the facility	0,65687	325	Recollected sample	0,60142
158	Removal / replacement of the identity by the patient without informing healthcare professional	0,65675	326	Empty sample container/tube	0,60119
159	Incorrect sample identification	0,65672	327	Lack of internal safety or sentinel event reporting system	0,60076
160	Late intervention for blue code status	0,65641	328	Cancellation of the record because a sample could not be obtained from the patient	0,60059
161	Overfeeding of the patient during the treatment process	0,65634	329	Loss of drugs	0,59818

162	Adverse effect (Notification)	0,65603	330	Infringement of patient privacy	0,59465
163	Lack of emergency and disaster management guidance	0,65508	331	Violation of FIFO rule	0,59377
164	Choosing wrong treatment	0,65455	332	Incorrect sample container/tube	0,58781
165	Wrong loading of drugs	0,65455	333	Stolen drugs	0,58769
166	Wrong methodology	0,65455	334	Unexpected death / loss of function	0,56093
167	Wrong time	0,65455			
168	Not informing the patient about the use of the medicine	0,65435			



BIOGRAPHY

Res. Asst. ZEYNEP TUĞÇE KALENDER

Faculty of Engineering / Industrial Engineering Department



E-Mail: tugce.simsit@marmara.edu.tr // ztsimsit@gmail.com

Phone: (216) 347 13 60 / 1219

Address: Marmara University–Göztepe Campus, Faculty of Engineering/ Industrial Engineering Department/A Block: Room: 226 Kadıköy, Istanbul, Turkey

<http://akademik.marmara.edu.tr/tugce.simsit/>

EMPLOYMENT

Industrial Engineering Department (Research Assistant)

MARMARA UNIVERSITY

(2013 – 2020)

/ Assisting problem solving sections of assigned lectures as a teaching assistant, controlling and checking the dissertations reports of students, undertaking examination related duties, coordination of internships of students, administrative duties (eq. scheduling of lectures, coordination of graduation process etc.)

GSM Sales Department (Long Term Internship)

LG Electronics

3 months period in 2010)

/ Sales Control and Reporting, New Product Development-workshops-, Product Analysis, Researching GSM Technologies

Purchasing Department (Assistant)

PLAST-MET GROUP

(2009-2010)

/ Quality management studies, analyses of customer orders, supplier relationships

EDUCATION

DOCTORATE (PhD)

MARMARA UNIVERSITY /Institute of Pure and Applied Sciences / Industrial Engineering (2013 – continue)

Doctoral Dissertation: Process Improvement through Decision Making Based Hybrid Methodologies and a Case Study

MASTER OF SCIENCE (MSc)

ISTANBUL TECHNICAL UNIVERSITY / Faculty of Management / Industrial Engineering (2011 – 2013)

MSc. Thesis: Effects of Change Point Management on Lean Accounting and a Case Study

BACHELOR OF SCIENCE (BSc)

ISTANBUL COMMERCE UNIVERSITY ÜNİVERSİTESİ / Faculty of Engineering and Design / Industrial Engineering (full scholarship) (2007 – 2011)

RESEARCH AREAS

Management Science, Multi Criteria Decision Making, Risk Management, Total Quality Management, Production and Service Systems, Lean Management, Supply Chain Management, Innovation Management

HONOURS and PRIZES

- TUBITAK National PhD Scholarship (2013-2017)
- TUBITAK National MSc Scholarship (2011-2013)

PROJECTS

- Optimization of Business Processes for Natural Gas Distribution Companies and Development of Business Management Model Based on Strategic Aligned Processes, RESEARCH PROJECT, Supervisor: ÖZTEMEL ERCAN, Supervisor: SENNAROĞLU BAHAR, Supervisor: ŞENVAR ÖZLEM, Supervisor: ÖZEL SEMİH, Supervisor: KALENDER ZEYNEP TUĞÇE,, 03 / 06/2019 (Continued)

PUBLICATIONS

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6. KALENDER ZEYNEP TUĞÇE, VAYVAY ÖZALP. *The Fifth Pillar of the Balanced Scorecard Sustainability*. Procedia - Social and Behavioral Sciences. Vol. 235. pp 76-83, 2016.

7. KALENDER ZEYNEP TUĞÇE, GÜNAY NOYAN SEBLA, VAYVAY ÖZALP. *Theory of Constraints A Literature Review*. Procedia - Social and Behavioral Sciences. Vol. 150. pp 930-936, 2014
8. KALENDER ZEYNEP TUĞÇE, VAYVAY ÖZALP, ÖZTÜRK ÖZGEN. *An Outline of Innovation Management Process Building a Framework for Managers to Implement Innovation*. Procedia - Social and Behavioral Sciences. Vol. 150. pp 690-699, 2014

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4. KALENDER ZEYNEP TUĞÇE, VAYVAY ÖZALP. *Healthcare Quality Management and A Case Study*
5. KALENDER ZEYNEP TUĞÇE, KILIC HÜSEYİN SELÇUK, TUZKAYA GULFEM, DASCIOGLU BUSRA GÜLNİHAL. *An Extended TOPSIS Methodology for the Electric Vehicles Charging Stations' Location Evaluation and an Application for Istanbul*

Book Chapters

1. KALENDER ZEYNEP TUĞÇE , VAYVAY ÖZALP *Çağdaş Endüstri Mühendisliği, "İnovasyon Yönetimi ve Yeni Ürün Geliştirme"*, Papatya Yayıncılık Eğitim, Edt. Oztemel, Ercan, Vol.1 2019 Vol 1, 2019
2. DAŞCIOĞLU BÜŞRA GÜLNİHAL, VAYVAY ÖZALP, KALENDER ZEYNEP TUĞÇE, *Lecture Notes in Management and Industrial Engineering in the Industry 4.0 Era, "Humanitarian Supply Chain Management: Extended Literature Review"*, Springer, Edt. Calisir, Fethi, Cevikcan, Emre, Camgoz-Akdağ, Hatice Vol.1, 2019 (ISBN:978-3-030-03317-0)
3. YAVUZTURK, HALDUN, KALENDER ZEYNEP TUĞÇE, VAYVAY ÖZALP, *Technological Developments in Industry 4.0 for Business Applications, "The Role of Universities in Industry 4.0 Era"*, IGI GLOBAL, Edt. Luis-Ferreira, Nuno Lopez, Joaquim, Silva, Goran D. Putnik, Maria Manuela Cruz-Cunha, Paulo Silva Avila, Vol.1 2019 (ISBN: 1522549366)
4. FIRAT SENİYE ÜMİT, AĞLAN CANAN, KALENDER ZEYNEP TUĞÇE, ÜLKÜ İLAYDA, BAYRAM GÖKÇEN, ERDEM MEHMET, *Handbook of Research on Driving Competitive Advantage through Sustainable Lean and Disruptive Innovation, "Lean Thinking via Business Intelligence Technologies and Innovation Process"*, IGI GLOBAL, Edt. Latif AL-Hakim, Xiaobu Wu, Andy Koronios, Yongyi Shou, Vol. 1., 2016 (ISBN:9781522501350)
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1. DASCIOGLU, BÜŞRA GÜLNİHAL, KALENDER, ZEYNEP TUĞÇE, TUZKAYA, GULFEM KILIC, HUSEYİN SELÇUK (2019). *Evaluation of Electric Vehicles Station Locations with an*

- Extended TOPSIS Methodology Using Probabilistic Linguistic Term Sets. In International Conference on Intelligent and Fuzzy Systems (pp. 820-828). Springer, Cham.
2. DAŞCIOĞLU BÜŞRA GÜLNİHAL, VAYVAY ÖZALP, KALENDER ZEYNEP TUĞÇE (2018) Humanitarian Supply Chain Management: Extended Literature Review, Global Joint Conference On Industrial Engineering and Its Application Areas
 3. PARLAK FIRAT, VAYVAY ÖZALP, KUNTER FULYA, KALENDER ZEYNEP TUĞÇE (2017). Literature Review of The RD Teams' Leadership to Manage Innovation", SIBR-Conference on Interdisciplinary Business Economics Research, Bangkok.
 4. KALENDER ZEYNEP TUĞÇE (2017) A General Overview of the Effects of Social Media to Healthcare Management, 6. International Congress on Current Debates in Social Sciences.
 5. KALENDER ZEYNEP TUĞÇE (2017) Medical Waste Management for a Sustainable Healthcare, International Symposium for Production Research.
 6. TUZKAYA UMUT RIFAT, TUZKAYA GÜLFEM, YILMAZER KADRIYE BÜŞRA, KALENDER ZEYNEP TUĞÇE (2017) A Logistics Allocation Model For Freight Villages: A Case Study For Turkey, The 15th International Logistics and Supply Chain Congress, 2017.
 7. KALENDER ZEYNEP TUGÇE, VAYVAY ÖZALP (2016). The Fifth Pillar of the Balanced Scorecard: Sustainability. 12th International Strategic Management Conference
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 9. KALEM GÖKHAN, KURT ONUR EMRE, VAYVAY ÖZALP, KALENDER ZEYNEP TUGÇE (2016). The Role of Mobile Devices and Applications in Supply Chains. 17th International Conference On Mathematics And Computers in Business and Economics
 10. AÇIKGÖZ INCI, VAYVAY ÖZALP, TUZKAYA GÜLFEM, SIMSIT ZEYNEP TUGÇE (2015). The Impact of Information Technology Applications on the Supply Chain Performance and a Case Study. XIII. International Logistics And Supply Chain Congress
 11. SIMSIT ZEYNEP TUGÇE, VAYVAY ÖZALP (2015). Performance Appraisals as a Quality Management Tool: Literature Review. ICOVACS 2015
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 13. ESEOGLU GÜNES, VAYVAY ÖZALP, SIMSIT ZEYNEP TUGÇE (2014). Assessment of Sustainability Performance Indicators in Manufacturing. Global Conference on Engineering and Technology Management
 14. SIMSIT ZEYNEP TUGÇE, VAYVAY ÖZALP, ÖZTÜRK ÖZGEN (2014). An Outline of Innovation Management Process: Building a Framework for Managers to Implement Innovation. 10. International Strategic Management Conference
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19. SIMSIT ZEYNEP TUGÇE, VAYVAY ÖZALP, SEVİM SEREN (2013). ERP Applications in Procurement Processes and Implementing Global Requisition System to a Firm in Pharmaceutical Industry. 1st International Conference On New Directions In Business, Management, Finance and Economics
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24. ŞİMŞİT ZEYNEP TUĞÇE, DURMUŞOĞLU MEHMET BÜLENT (2013) Yalın Maliyet Muhasebesi ve Bir Uygulama, Makina Mühendisleri Odası Yalın Dönüşüm Endüstri Mühendisliği Bahar Konferansları, İzmir
25. BİRGÜN SEMRA, ŞİMŞİT ZEYNEP TUĞÇE, ÖZTEPE TUBA (2011) Bir Çağrı Merkezinde Müşteri Şikayetlerinin Düşünce Süreçleri İle Değerlendirilmesi", 11. Üretim Araştırmaları Sempozyumu İstanbul

TEACHING EXPERIENCE

- Teaching Assistant (Problem Solving Sections)
 - Production Planning and Control I (2017-2018-2019 Fall Semesters)
 - Production Planning and Control II (2017-2018-2019 Spring Semesters)
 - Operations Research II (2018-Spring Semester)
 - Decision Making (2014-2015 Fall Semesters)
 - Project Management (2015-2016 Spring Semester)