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A New Holistic Risk Analysis Approach Based on the House of Quality

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Abstract

Risk management is a crucial process s that consists of many components. In risk management, different processes are considered, namely, risk identification, risk assessment, determination of preventive actions and monitoring. In this study, a novel risk management approach in which all risk processes are integrated is proposed. In this context, a holistic risk management approach based on the house of quality approach is introduced, and an eight-step creation process is defined. The proposed approach was applied for a primary health care center, and the hazards, risks to be occurred by these hazards, and preventive suggestions were presented. In the case study, twenty-five hazards were identified and eleven risks related to twenty-five hazards were identified and ranked. According to the risk priority numbers, five preventive actions were suggested and evaluated.

Keywords: Risk management, House of quality, Holistic risk analysis, Risk mitigation

Kalite Evi Yaklaşımına Dayalı Yeni Bir Holistik Risk Analizi Yöntemi

Öz

Risk yönetimi, birçok bileşenden oluşan çok önemli bir süreçtir. Risk yönetiminde, risk tanımlama, risk değerlendirme, önleyici faaliyetlerin belirlenmesi ve izleme olmak üzere farklı süreçler dikkate alınmaktadır. Bu çalışmada, tüm risk süreçlerinin entegre edildiği yeni bir risk yönetimi yaklaşımı önerilmiştir. Bu kapsamda, kalite evi yaklaşımına dayalı bütüncül bir risk yönetimi yaklaşımı tanımlanmıştır ve yeni yönteme ait sekiz aşamalı oluşturma planı açıklanmıştır. Önerilen yaklaşım bir birinci basamak sağlık kuruluşu için uygulanmış ve tehlikeler, bu tehlikelerin yaratacağı riskler ve önleyici öneriler sunulmuştur. Vaka çalışmasında, yirmi beş tehlike tanımlanmış ve yirmi beş tehlikeyle ilgili olarak on bir risk belirlenmiş ve sıralanmıştır. Risk öncelik sayılarına göre beş önleyici faaliyet önerilmiş ve değerlendirilmiştir.

Anahtar Kelimeler: Risk yönetimi, Kalite evi, Holistik risk analizi, Risk azaltma

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1. INTRODUCTION

Sustainability is a term that refers to trying to create and maintain the conditions within considering an inherently efficient way to help current and future generations [1]. This concept changes the production environment in a way that puts the environment and human-being in focus. In addition to achieving sustainability, regulations are enforced by firms to consider the environment and occupational health. Accordingly, the firms are concerned with more environmental and efficient production strategies considering the environmental, occupational health, and safety hazards. The hazards may cause staff casualties and financial losses, besides interruptions on service and high-quality products. Healthcare systems need more attention to the hazards that may occur, as they provide emergency services and responsible for patients' health.

In healthcare systems, there are some specific activities for avoiding and reducing losses given as follows [2]:

- Creating a risk identification mechanism such as reports from medical records, incidents, staff refs, patient complaints, and quality improvement techniques,
- Establishing and maintaining good relationships among systems members who are quality team, medical staff, infection controller and other relevant members,
- Building policies, procedures, qualitative and statistical reports about risk management,
- Creating educational programs for staff on different risk management topics,
- Considering and managing the contract risks that may occur from affiliation, construction, leasing or management agreements,

Healthcare systems are different from other systems due to infection and epidemical risks. According to World Health Organization statistics, 7% of hospitalized patients in developed countries and 10% of hospitalized patients in developing countries will be affected by at least one healthcare-associated infection at any given time [3]. Considering these reasons, it makes it hard to manage risk analysis and management processes on healthcare systems.

Risk can be defined as a random and possibly occurring event; however, it affects the organizational objectives in a negative way when it occurs [4]. In order to avoid such negative impacts, risks need to be carefully determined, probability and impacts of the risks when they occur should be analyzed in risk analysis studies. As seen in Figure 1, risk analysis and management is a process that starts from risk definition, which focuses on identifying hazards, continues with the risk assessment phase, which evaluates these hazards. Then, the corrective activities are planned in the mitigation phase, and finally the risks are tracked in the monitoring phase.

The risk analysis and risk management process are recurrent; therefore, each phase interacts with each other in different ways. Firstly, a hazard may cause more than one risk. Secondly, different risks may positively or negatively affect each other, and finally, corrective action may mitigate more than one risk and make this action privileged from other actions. Therefore, a holistic approach is needed to take into account these interactions between risk analysis and management process steps.

In this study, a novel holistic risk analysis and management approach is proposed to deal with the interaction between identification, assessment, mitigation, and monitoring processes. Quality function deployment (QFD) based risk analysis schema is applied for this purpose. QFD is a tool that improves quality by using mathematical analysis, which focuses on functional relationships by appending a series of matrices [5]. The mathematical analysis provides to translate customers' voice to functional company requirements by using visual and integrated thinking.

The new holistic method makes it possible to consider the risk analysis and management process in a comprehensive way as following (i) assessing different hazards and their importance values regarding caused risks, (ii) assessing the hazards precisely with considering all risks that may occur, (iii) quantifying interaction between risks, and (iv) ordering the corrective actions according to their benefits. Unlike conventional risk analysis methods, the new method has a more integrated view of risk analysis and management processes. The method can be considered as an effective way to manage many hazards, risks, and corrective actions together. For this aim, the method is applied to a primary care clinic with various hazards such as fire, explosion, ergonomics, and infections.

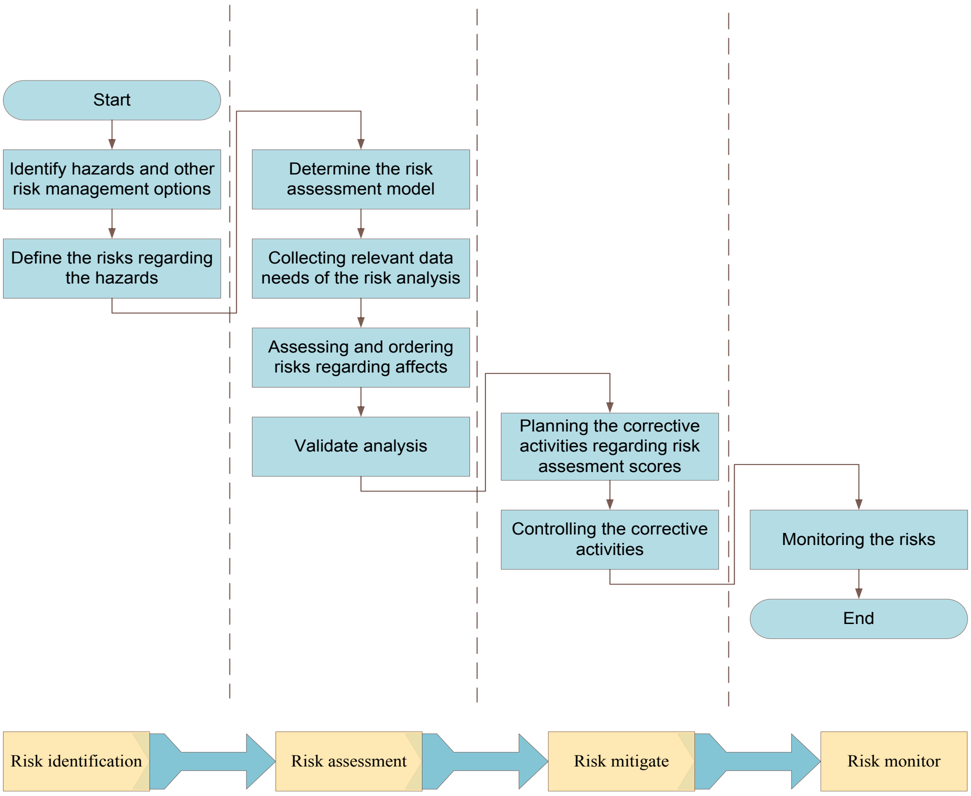


Figure 1. Risk analysis and management process

2. BACKGROUND

There are numerous studies on occupational health and safety in which different risk analysis approaches are used in different applications. While various applications of QFD, such as new product design, have been considered in the previous studies, the QFD method is one of these approaches applied in risk assessment studies. Besides, the integration of QFD with other risk analysis methods has attracted the attention of researchers recently. In their study, Fargnoli et al. have combined QFD with Hierarchical Task Analysis and Human Error Assessment and Reduction Technique, and risks in agricultural practices are analyzed [6]. In another study, Failure Mode and Effect Analysis (FMEA) and QFD methods are used to conduct risk analysis at the robot design stage in determining reliability [7]. Another study integrates QFD and FMEA approaches with 2-tuple linguistic representation [8]. In their study, Lin et al. proposed an approach which integrates QFD and FMEA with goal programming in the new product design stage [9].

Kaddoura et al. proposed a method using QFD and DEMATEL techniques. In their study QFD and DEMATEL approaches are incorporated in the manholes risks analysis system [10]. In another study, QFD, FMEA, and Analytical Network Process are integrated for developing a fuzzy risk assessment approach [11]. One of the studies proposes a customer-oriented risk assessment approach acquired by integrating FMEA and QFD [12]. In their study, Chen has evaluated the service demand risks using FMEA and QFD methods [13]. QFD based risk assessment approach is proposed for the construction industry [14]. In the study, hazards are determined using a fuzzy analytic process and evaluated by using FMEA. Cinar and Cebi have proposed a hybrid risk assessment method for mining sector based on QFD, Fuzzy Logic and AHP techniques [15]. Haktanır has proposed a new method with an integrated picture fuzzy QFD and FMEA for the risk analysis of Digital Transformation [16].

Holistic risk analysis aims to evaluate risks comprehensively by focusing on different parameters collectively. In the literature, there are a number of applications of holistic risk analysis. In their study, Colombo has proposed an approach that considers human, technological, and organizational elements by a holistic approach called HORAM [17]. In another study, human and organizational factors have been incorporated with a holistic approach while considering uncertainties [18]. In another holistic risk analysis study with QFD, an approach called House of Safety has been proposed which evaluates the risks in machine design considering human-machine interaction [19]. In their study, Spears has handled information technology-based risks and considered a holistic approach that is focusing on technology, information, people, and processes [20]. Zhang and Mohandes used hybrid Z-numbers based multi-criteria decision-making method and proposed a holistic Z-numbers based risk management framework on occupational health and safety in green building construction projects [21]. Mishra et al. have proposed an integrated approach in order to assess microgrid's resilience in a holistic way [22]. Zhou et al. have proposed a holistic risk assessment framework based on Bayesian Network Modelling [23]. Abba et al. have proposed a risk management framework for renewable energy investments. They used a holistic approach in their study [24].

The medical systems are vital for humans; therefore, risk identification, assessment, and prevention are essential. There are a number of studies focus on different medical systems-based risk assessments such as, oncology [25], emergency department [26] and multiple departments [27]. Liu has proposed improved FMEA techniques for proactive healthcare risk analysis [28]. These studies focus only on the risk assessment procedure in risk management using different methods. Risk assessment studies are generally considered for prioritizing hazards that are related to the system. Moreover, a hazard may cause more than one risk, but in general this is neglected. Accordingly, there is a need to consider the risk assessment, prioritize, analyze, and prevent processes in an integrated manner. Such an approach becomes even more critical in systems such as health systems that are open to risks due to the service provided and where service level is mandatory. A QFD-based system is a useful approach to meet the needs of this integrated structure. This study differs from the studies in the literature in this aspect. Therefore, the proposed approach is applied to a primary healthcare center to ensure the holistic risk management process.

2.1. Quality Function Deployment

Quality function deployment is a powerful tool that provides decision support by using numerical indicators with graphical representations [29]. The first matrix of quality function deployment is the house of quality (HOQ), and it provides the transition from customer to product characteristics [30]. These properties make a powerful tool for new product development and other applications. HOQ consists of six parts, as shown in Figure 2. The steps of the HOQ is given as follows [31]:

1. Customer expectations about the products are handled in the customer requirements section.

2. In the customer requirements section, the relative importance of customer requirements is also prioritized.
3. Benchmark matrices are calculated by acquiring competitive assessment.
4. The engineering characteristics determine technical requirements about the products.
5. Customer requirements and engineering characteristics are ranked in order to calculate the relationship matrix.
6. Engineering characteristics may positively or negatively correlate; therefore, the correlations between the engineering characteristics are determined in the correlation matrix.
7. Finally, technical requirements are ranked based on the targets of the importance matrix and the best alternative is selected accordingly.

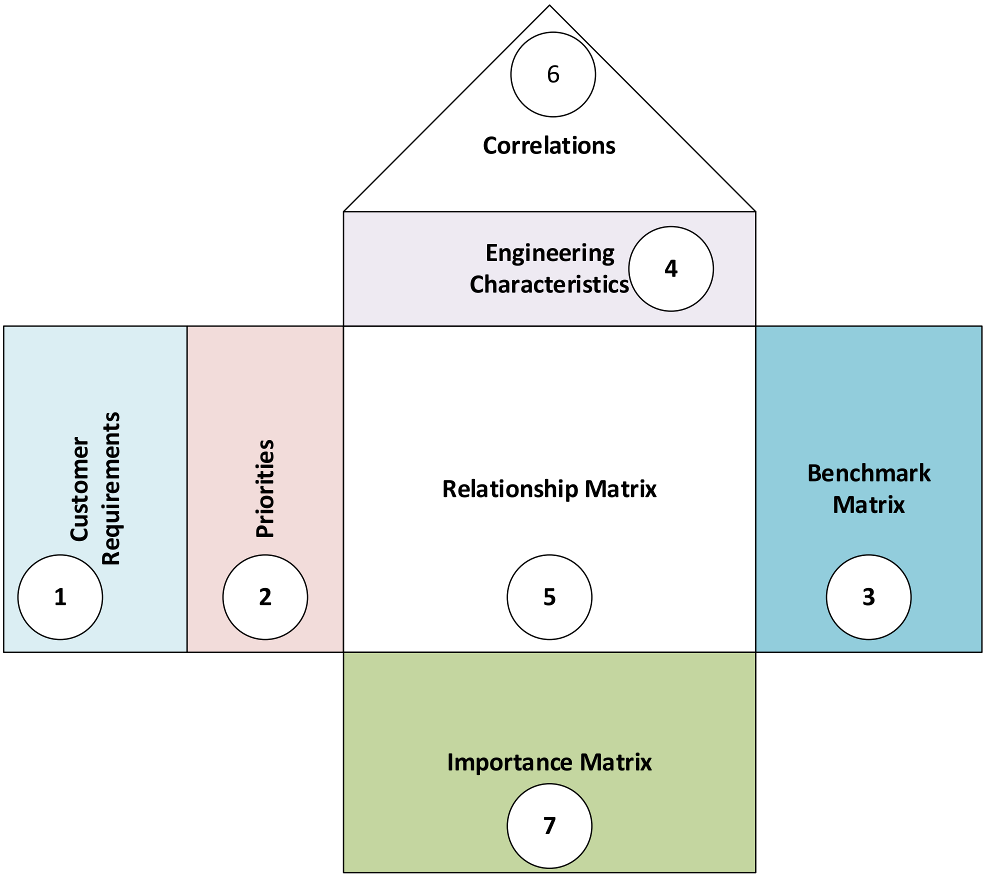


Figure 2. Basic HOQ structure

3. THE HRAM APPROACH

HOQ provides a holistic approach that considers both single and correlated effects of customer requirements, technical characteristics, and comparing alternatives in an integrated manner. It makes it suitable for the HOQ approach to be used as a holistic approach in risk analysis, as outlined in Figure 3. The steps of the proposed holistic risk analysis method (HRAM) and the calculations done in these steps are as follows:

Step 1. Identification of hazards

In this step, hazards in the system are identified. Let i be the indices of hazards in the system.

Step 2. Determination of probability values

The risks in the hospital are mostly human-oriented. In order to determine the probability values, the probability scale for each hazard is calculated using the probability scale in Table 1. The scale has been defined based on expert opinion. Let p_i be the probability value of hazard i.

Table 1. Probability scale

Value	Level	Description
1	Very low	The occurrence of the hazard is less than $1/10^4$
2	Low	The occurrence of the hazard is between $1/10^4$ and $1/10^3$
3	Moderate	The occurrence of the hazard is between $1/10^2$ and $1/10^3$
4	High	The occurrence of the hazard is between 1/10 and $1/10^2$
5	Very high	The occurrence of the hazard is greater than 1/10

Step 3. Identification of risks

In this step, the risks of the system are defined. The engineering characteristics aim to maximize or minimize in classical HOQ; however, all risks are tried to be minimized in risk analysis. The risks are indexed by j and l.

Step 4. Determination of the severity values

In classical risk analysis studies, each hazard may cause only one risk which makes it hard to evaluate the severity of the risks. However, a hazard may cause more than one risk. Therefore, it is hard to evaluate the severity of the hazard. In the proposed holistic approach, severity values are applied using the scale given in Table 2. Similar to the probability scale, the severity value of the hazard i and the risk j is denoted as s_{ij}.

Table 2. Severity scale

Value	Level	Description
1	Very low	Minor injury
2	Low	Needing first aid
3	Moderate	Work loss less than three days
4	High	Work loss more than three days
5	Very high	Fatality for human

Step 5. Calculation of the risk priority numbers

In most risk assessment studies, the risk priority number is calculated to rank the hazards. In this study, the risk priority number is calculated by using Equation 1. Let r_i denote the risk priority number of hazard i.

$$r_i = p_i * \sum_{i}^{N} s_{ij} \tag{1}$$

Step 6. Determining preventive actions

As this approach is holistic, it is crucial to determine the corrective activities. Preventive actions provide to avoid risks caused by hazards. In this step, there may be many preventive actions that affect hazards. Moreover, there is a prioritization of the preventive actions according to risk priority numbers of hazards and managerial decisions. Therefore, preventive actions can be associated to alternative benchmarks in the classic HOQ.

The question that may arise about preventive actions is how to measure these activities' impact on hazards. Let k denote the index of the preventive actions and w_{ik} denote the effect of the preventive action k on the hazard i. The preventive action scale is given in Table 3.

Table 3. The scale of preventive actions

Value	Effect
1	Eliminate the risk
3	Eliminate the risk majorly
5	Eliminate the risk on average
7	Eliminate the risk minorly
10	Not-improved the current risk
2,4,6,8,9	Intermediate values

Step 7. Indicating the correlations

The risks may correlate with each other. For instance, a collapse risk may also cause an explosion risk. Therefore, both positive and/or negative correlations are included in this holistic approach. Let c_{jl} denote the correlation between risk j and risk l. The valid range of the c_{jl} is {-1, 0, +1} where negative correlation, no correlation and positive correlation are indicated with -1, 0 and +1, respectively. The correlation is similar to relationship between technical requirements in the classical QFD.

Step 8. Calculating the importance values of the preventive actions

The final step of the approach is to calculate the importance values of the preventive actions and the current situation on the risks. The importance values (x_{kj}) can be calculated by using the Equation 2.

$$x_{kj} = \sum_{i=1}^{N} \frac{p_i * s_{ij} * w_{ik}}{10} + \sum_{i=1}^{N} \sum_{l=1}^{M} \frac{p_i * s_{il} * w_{ik} * c_{jl}}{10} \qquad (2)$$

The first term focuses on the current risks, and the second term calculates the total correlated risks. Both terms are divided to 10 to normalize the total score by considering the maximum value of from Table 3. Relative importance value (I_{kj}) according to these values can be calculated as Equation 3. Note that the current system is marked as the first preventive action, and for this reason, the relative importance value of the current system equals 0.

$$I_{kj} = \frac{x_{1j} - x_{kj}}{x_{1j}} \qquad (3)$$

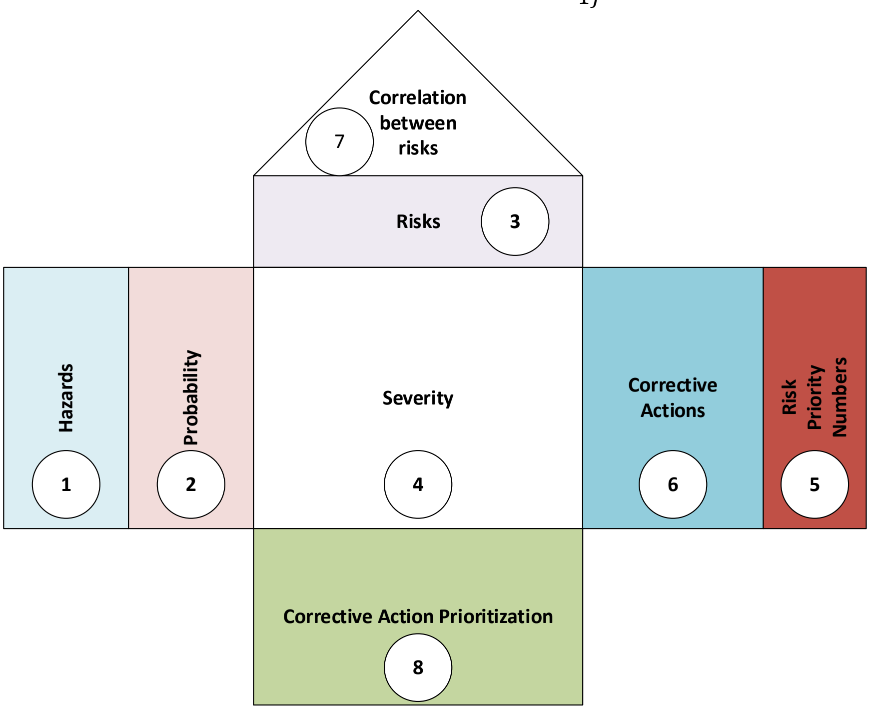


Figure 3. Graphical representation of HRAM

4. CASE STUDY

The proposed holistic approach is applied to a primary healthcare center in Adana, Turkey. Adana is one of the biggest cities in Turkey, having about 2.3 million population. Health practices in Turkey have increased with the impact of the COVID19 pandemic, and while the per capita health expenditure was 2 thousand 997 TL in 2020, it increased by 40.3% in 2021 to 4 thousand 206 TL [32].

In Turkey, each citizen has a dedicated primary care physician and a primary health care center. Primary health care centers provide preventive health services and primary care diagnosis, treatment, and rehabilitative health services for individuals and family members located near their place of residence or in a place where they can reach easily. According to the Turkish Minister of Health Statistics, there are about 26000 primary health care units in about 8000 centers, and around 3000 people access the service in each unit [33]. Furthermore, primary health care centers are crucial in the healthcare system. For this reason, a primary health care center is selected as a case for the holistic risk approach.

Three risk analysis experts having at least five years of experience identify and evaluate the hazards, risks, risk priority numbers, preventive actions, and the effects of preventive actions. There is a need to achieve consensus to make group decisions in rating probabilities, severities, and preventive actions. The Delphi method has been used to find the final values based on these three expert responses.

The results obtained from the application are given step by step as follows:

Step 1. Identification of hazards

There are 25 different hazards identified in the system with various aspects: safety, infection, allergic and managerial aspects. The first column of Table 4 shows the defined hazards in the system.

Step 2. Determination of probability values

The probability (p_i) values for each hazard are selected from the scale given in Table 1 and the p_i values are given as the second column of Table 4. According to the results, the most probable risk is infection spreading (H7), lack of medical waste temporary storage area (H17), and respiration transmitted disease hazards (H18).

Step 3. Identification of risks

In the system, 11 different risks are defined, which are collapse, fire, explosion, falling, infection, transmitted disease, irritation, health problem, injury, electric shock, and allergic disease.

Step 4. Determination of the severity values

The severity (s_{ij}) values for each risk and hazard pairs are selected from Table 2 and s_{ij} values are given in Table 4.

According to results, the most rated hazards for severity are deformed electric cables and plugs (H15) and lack of standards for controlling biological risks (H25).

Step 5. Calculation of the risk priority numbers

Risk priority numbers (r_i) for 25 hazards in the system are calculated by Equation 1 and the values are given in Table 4. According to risk priority numbers, the most crucial risk is respiration transmitted diseases (H18). The second most significant risk is the lack of standards for controlling biological risks (H25).

Table 4. Risk assessment matrix

Hazards (i)		**Probability**	**Risks (j)**											**Risk Priority Numbers**
		p_i	Collapse	Fire	Explosion	Falling	Infection	Transmitted disease	Irritation	Health problem	Injury	Electric shock	Allergic disease	r_i
H1	Earthquake occurrence	2	5											10
H2	Natural gas connections	2		4	5									18
H3	Electric equipment	3		5										15
H4	Bad stored materials	3				1	3							12
H5	Existing kitchen department and propane cylinders usage	2		4	5									18
H6	Oxygen cylinder usage	3		4	5									27
H7	Infection spreading due to lack of air ventilation	5						3						15
H8	Chemical equipment usage	3							3					9
H9	Insufficient health and safety markings	4								3	3			24
H10	Lack of near-miss recording	3								3	3			18
H11	Lack of maintenance	3								3	3			18
H12	Lack of running instructions for a centrifuge device	3					4							12
H13	Inflammable and explosive equipment positioned near power generator	3		4	5									27
H14	Messy electric cables around the electric panel	2		4								4		16
H15	Deformed, uninsulated, old, broken electric cables and plugs	2		4		2						4		20
H16	Non-usage of fire extinguisher system and fire emergency plan	3		5										15
H17	Lack of medical waste temporary storage area	5					4							20
H18	Respiration transmitted diseases	5					4	4						40
H19	Lack of making a waste management plan	4						3		2				20
H20	Lack of collection and separation of contaminated packaging materials	4						4		2				24
H21	Lack of infected liquids and chemicals cleaning kit	4									3			12
H22	Calibration, periodic control, and maintenance absence for contaminated medical equipment at the sterilization unit	4						4						16
H23	Lack of cleaning plan	2						3						6
H24	Biocidal products usage for insect controlling	3								2			3	15
H25	Lack of usage of national or international standards for controlling biological risks	3					5	5						30

Step 6. Determining preventive actions

In the system, preventive actions for each hazard are identified. Preventive actions are clustered since some of them have similar characteristics. Finally, five main preventive actions are listed as follows: regulation compliance (A1), improving relationships with partners (A2), procedure, documentation (A3), facility layout improvement (A4), and new equipment purchasing (A5). Preventive action groups determined in this study are given in Table 5. The preventive action groups improvement values found according to the scale given in Table 3. and given in Table 5,

Table 5. The scale of preventive actions

Hazards	Preventive actions	Groups					Improvement (w_{kj})				
		A1	A2	A3	A4	A5	A1	A2	A3	A4	A5
H1	Achieving compliance with earthquake regulations	✓					3	10	10	10	10
H2	Creating licensed supplier relationships		✓				10	2	10	10	10
H3	Achieving regulation compliance for electric infrastructure	✓					2	10	10	10	10
H4	Creating and achieving the material stowing procedure			✓			10	10	5	3	10
H5	Re-positioning the propane cylinders and planning for controlling with gas detector				✓		10	10	10	3	10
H6	Positioning and storing regarding safety instructions				✓		10	10	10	4	10
H7	Improving air conditioning system					✓	10	10	10	10	1
H8	Building and tracking material safety system					✓	10	10	10	10	3
H9	Proper marking			✓			10	10	5	10	10
H10	Developing a reporting system			✓			10	10	7	10	10
H11	Creating maintenance plan			✓			10	10	7	10	10
H12	Creating working instructions			✓			10	10	5	10	10
H13	Positioning away from the power generator				✓		10	10	10	3	10
H14	Avoiding near storage inflammable, burning or chemical materials to the electric panel, creating dielectric field near to electric panel, improving electric infrastructure				✓		10	10	10	3	10
H15	Higher cable positioning and changing more resistive cable routes				✓		10	10	10	2	10
H16	Creating a fire plan and using a fire extinguisher			✓			10	10	3	10	10
H17	Setting temporary storage container for medical wastes regarding regulations				✓		10	10	10	1	10
H18	Determining the biological risk group and applying suitable isolation cautions			✓			10	10	3	10	10
H19	Developing a waste management plan for collecting, decomposing, temporary storing and cleaning, and disinfecting wastes			✓			10	10	3	10	10
H20	Decomposing the wastes as contaminated and non-contaminated materials					✓	10	10	10	10	1
H21	Acquiring cleaning kit and putting the safe cleaning instructions banners					✓	10	10	10	10	1
H22	Calibrating sterilization equipment and creating maintenance plans that accordance with current regulations	✓					1	10	10	10	10

Table 5. (Continued)

H23	**Creating cleaning plan with considering storing conditions, material labels, warnings, and personal protective equipment usage information**			✓			**10**	**10**	**2**	**10**	**10**
H24	Controlling biocidal products regarding biocidal usage regulations	✓					1	10	10	10	10
H25	Implementing national/international standards for avoiding transmission of biological infections or creating own work procedure for this aim	✓					1	5	10	10	10

Step 7. Indicating the correlations between risks

In this study, some of the risks correlate with others positively. Table 6 shows the correlations between the risks. For instance, falling may cause different risks such as fire, health problems, and injury; therefore, it is marked as "+1"— here, all empty cells equal to 0.

Table 6. Correlations in risks

		Risks										
		Collapse	Fire	Explosion	Falling	Infection	Transmitted disease	Irritation	Health problem	Injury	Electric shock	Allergic disease
Risks	Collapse			**+1**								
	Fire				**+1**							
	Explosion	**+1**										
	Falling		**+1**						**+1**	**+1**		
	Infection						**+1**					
	Transmitted disease					**+1**			**+1**			
	Irritation											**+1**
	Health problem				**+1**		**+1**					
	Injury				+1							
	Electric shock											
	Allergic disease							+1				

Step 8. Calculating the importance values of the preventive actions

The importance values for the preventive actions are calculated using Equation 2 and summarized in Table 7. Each of these preventive actions affects at least one hazard. Therefore, it is essential to rank these corrective actions. The importance values are expressed relative to the current system. The facility layout improvement found to be the best improvement.

Table 7. % Importance values of the preventive actions

Importance values of the preventive actions (X_{kj})	Risks										
	Collapse	Fire	Explosion	Falling	Infection	Transmitted disease	Irritation	Health roblem	Injury	Electric shock	Allergic disease
Current system	60	93	60	187	176	228	18	159	42	16	18
Regulation compliance	53	81	53	169.6	134.6	181.2	9.9	125.7	42	16	9.9
Improving relationships with partners	52	86.6	52	180.6	161	213	18	151.5	42	16	18
Procedure, documentation	60	81	60	146.6	124.3	159.3	18	113.3	30.6	16	18
Facility layout improvement	33.5	54.5	33.5	148.5	151.7	203.7	18	153.7	42	4	18
New equipment purchasing	60	93	60	169	148.1	192.9	11.7	123.9	31.2	16	11.7

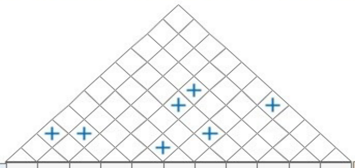
The importance values of the preventive actions are determined by taking into account the relative improvement values given in Table 8. According to the results, the most crucial preventive action is the facility layout improvement (A4). Regulation compliance (A1) and procedure and documentation (A3) ranked as second. Less necessary preventive action is improving relationships with partners (A2). It is expected, because improving relationship with partners affects only one hazard.

Table 8. The relative importance of the preventive actions

Relative Importance of the Preventive Actions (I_{kj})	Risks										
	Collapse	Fire	Explosion	Falling	Infection	Transmited disease	Irritation	Health problem	Injury	Electric shock	Allergic disease
Regulation compliance	0.12	0.13	0.12	0.09	0.24	0.21	0.45	0.21	0.00	0.00	0.45
Improving relationships with partners	0.13	0.07	0.13	0.03	0.09	0.07	0.00	0.05	0.00	0.00	0.00
Procedure, documentation	0.00	0.13	0.00	0.22	0.29	0.30	0.00	0.29	0.27	0.00	0.00
Facility layout improvement	0.44	0.41	0.44	0.21	0.14	0.11	0.00	0.03	0.00	0.75	0.00
New equipment purchasing	0.00	0.00	0.00	0.10	0.16	0.15	0.35	0.22	0.26	0.00	0.35

The overall HRAM graph is drawn in Figure 4. The results obtained from the novel holistic approach show that considering the severity value of multiple risks and hazards creates more probable and severe hazards than the r_i values. Furthermore, this approach integrates the risk assessment and mitigation processes. Finally, HRAM provides a graphical representation for ease of managing the whole risk analysis processes. It shows that the HRAM provides more insights and managerial benefits.

HOLISTIC RISK ANALYSIS APPROACH



+	Positively Correlated	+1
—	Negatively Correlated	-1

	Probability	Collapse	Fire	Explosure	Falling	Infection	Transmitted disease	Irritation	Health problem	Injury	Electric shock	Allergic disease	Current System	Regulation Complience	Improving relationship with partners	Procedure, documentation	Facility layout improvement	New equipment purchasing	Risk Priority Number
Earthquake occurence	2	5											10	3	10	10	10	10	10
Natural gas connections	2		4	5									10	10	2	10	10	10	18
Electric equipment	3		5										10	2	10	10	10	10	15
Bad stored materials	3				1	3							10	10	10	5	3	10	12
Existing kitchen department and propoane cylinders usage	2		4	5									10	10	10	10	3	10	18
Oxygen cylinder usage	3		4	5									10	10	10	10	4	10	27
Infection spreading due to lack of air ventilation	5						3						10	10	10	10	10	1	15
Chemical equipment usage	3							3					10	10	10	10	10	3	9
Insufficient health and safety markings	4								3	3			10	10	10	5	10	10	24
Lack of near miss recording	3								3	3			10	10	10	7	10	10	18
Lack of maintanance	3								3	3			10	10	10	7	10	10	18
Lack of running instructions for centrifuge device	3					4							10	10	10	5	10	10	12
Imflammable and explosive equipment positioned near power generator	3		4	5									10	10	10	10	3	10	27
Messy electric cables around the electric panel	2		4								4		10	10	10	10	3	10	16
Deformated, uninsulated, old, broken electric cables and plugs	2		4		2						4		10	10	10	10	2	10	20
Non-usage of fire extinguisher system and fire emergency plan	3		5										10	10	10	3	10	10	15
Lack of medical waste temporary storage area	5					4							10	10	10	10	1	10	20
Respiration transmitted diseases	5					4	4						10	10	10	3	10	10	40
Lack of making waste management plan	4						3		2				10	10	10	3	10	10	20
Lack of collection and seperation of contaminated packaging materials	4						4		2				10	10	10	10	10	1	24
Lack of infected liquids and chemicals cleaning kit	4									3			10	10	10	10	10	1	12
Calibration, periodic control and maintanence absence for contaminated medical equipments at the sterilization unit	4						4						10	1	10	10	10	10	16
Lack of cleaining plan	2						3						10	10	10	2	10	10	6
Biocidal products usage for insect controling	3								2			3	10	1	10	10	10	10	15
Lack of usage of national or international standarts for controling biological risks	3					5	5						10	1	5	10	10	10	30

	Collapse	Fire	Explosure	Falling	Infection	Transmitted disease	Irritation	Health problem	Injury	Electric shock	Allergic disease
Current System	60	93	60	187	176	228	18	159	42	16	18
Regulation Complience	53	81	53	169,6	134,6	181,2	9,9	125,7	42	16	9,9
Improving relationship with partners	52	86,6	52	180,6	161	213	18	151,5	42	16	18
Procedure, documentation	60	81	60	146,6	124,3	159,3	18	113,3	30,6	16	18
Facility layout improvment	33,5	54,5	33,5	148,5	151,7	203,7	18	153,7	42	4	18
New equipment purchasing	60	93	60	169	148,1	192,9	11,7	123,9	31,2	16	11,7

Figure 4. The HRAM graph for the primary healthcare center

6. CONCLUSION

Risk management is a broad subject applied in various types of organizations. The risk identification, assessment, mitigation and monitoring phases are the phases of the risk management processes. It is essential to integrate each of these phases. In this study, a holistic risk analysis approach based on HOQ is proposed. The holistic risk analysis approach differs from classical HOQ applications by adding calculations to perform the risk analysis. Conventional qualitative risk analysis methods are applications that evaluate all management processes independently, mostly supported by an expert opinion and based on the calculations made with different parameters such as probability and severity. In addition, data-driven advanced risk analysis methods are also available. There are limitations of the conventional risk analysis method since the issues such as the results obtained from the assessed risks and how they can be eliminated are independent. It is essential to integrate each of these phases. In this study, an 8-step holistic risk analysis approach based on HOQ is proposed. Thus, the entire risk analysis process (identification, assessment, mitigation and monitoring) and the relationships between these processes can be evaluated simultaneously with the HRAM approach.

Furthermore, the proposed holistic risk analysis provides a visual graphical method that monitors the overall risk management studies in a single chart. The proposed approach is applied to a primary health care center in Turkey, and the results show that the holistic risk analysis approach affects the risk assessment and mitigation processes significantly. According to the case study results, facility layout improvement was found to be most crucial preventive action so if 7 of the total 11 risks can be eliminated, there's a possibility that around ten percent improvement than the current system may occur. The results show that risks are expected to decrease when procedures and workflows are created correctly.
The proposed method is applicable when integrated risk analysis is required in different systems such as production processes and service processes. The other applications of the proposed approach may be considered as a future suggestion. Moreover, the fuzzy logic approach may be included to improve the holistic risk analysis approach further.

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