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Article

Integrated risk-oriented design method in architecture

Semih Serkan USTAOĞLU[1,*], Sevgül LİMONCU[2]

[1]*Department of Architecture, FSMVU Faculty of Arts, Design and Architecture, Istanbul, Türkiye*
[2]*Department of Architecture, YTÜ Faculty of Architecture, Istanbul, Türkiye*

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ABSTRACT

Safe building design is a significant architectural design criterion in ensuring the health and safety of users. In Türkiye, recent buildings produced through constraints concentrated on resilience against disasters such as earthquakes, fires, floods, as well as those built with experiential traditional design approaches have proven inadequate for ensuring user safety and health. To prevent potential accidents involving users, a comprehensive approach is needed that, in addition to disaster-oriented design criteria, factors related to the building and its immediate surroundings, users, functions, and risks are considered. Consequently, an "Integrated Risk-Oriented Building Design" method is developed based on the traditional design approach in which risk factors and safety criteria are determined, necessary action steps sequences are organized precisely, user safety is ensured, and it is supported by decision-making and calculation methods whereby validating its applicability scientifically. Study stages include; literature review, developing a new method proposal by integrating existing decision-making and calculation systems with the traditional design method, and a case study testing the developed method. The proposed method aims to minimize built environment's risks within the structure and its surroundings per the identified criteria. It is believed that when the Integrated Risk-Oriented Building Design method is properly implemented by designers and experts, potential risks that users might encounter will be eliminated or mitigated, leading to the production of safe and healthy designs. Moreover, the proposed method is expected to serve as a guide for future studies that can be further developed through scientific research and respond accurately to evolving needs.

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INTRODUCTION

The need for shelter arose from the necessity for humans to protect themselves from various challenging environmental conditions, maintain their lives in a safe and healthy environment that can withstand the adversities of nature, and their inability to feel safe in open spaces since the beginning of their existence. Buildings and shelters provide people with a safe environment, enabling them to live under suitable conditions. In this sense, buildings and their immediate surroundings are crucial for individuals to feel safe. However, over time, buildings have increasingly deviated from providing a safe environment due to factors

***Corresponding author**
*E-mail adres: sustaoglu@fsm.edu.tr

such as irregular urbanization, profit-driven concerns, rapid production, improperly used materials, faulty constructions, disasters, and departure from user- and environment-oriented design processes. Consequently, users are confronted with threats and dangers arising from these issues within the building and its immediate surroundings, which negatively impact their lives.

Many different approaches other than the traditional design approach have been developed in architectural design. However, the traditional design approach is widely used in the world. Through the traditional design approach, it is assumed that requirements will be met and hazards will be avoided when standards are applied by following appropriate sequences based on experience. However, the risk-oriented design method assumes that safety vulnerabilities will increase in traditional approach practices if the method is not adhered to, standards are violated, or there is a lack of experience (McDowell & Lemer, 1991). The traditional design approach, while inherently facilitating a faster and easier production process, is a system that increases the likelihood of safety risks. As it does not rely on quantitative data, it negatively impacts the awareness of both users and designers. The phases of the traditional design approach are presented in Figure 1.

Safety issues are of critical importance in architectural design, and defects not only represent damage to the design itself but also negatively impact the user's ability to live healthily within the building during when it is occupied (Isa et al., 2011). Buildings designed without consideration for user safety, incidents with dire results such as bodily injuries, internal organ damages, internal bleeding, fractures and dislocations in the skeletal system, burns, scalding, poisoning, and even death may be encountered (Güler & Çobanoğlu, 1994). In this context, it is necessary to identify built environment problems in and around the building through research and to investigate their root causes.

The primary cause of the issues mentioned within and around the building is the safety vulnerabilities created by the traditional design approach. As a result of these vulnerabilities, users are exposed to significant factors and accidents. When examining the role of accidents among causes of death, they rank third in Türkiye and fifth in Switzerland, Bulgaria, and the United States (Ural & Gün, 2008). In the United Kingdom, there are 2.7 million indoor accidents annually, resulting in 5,000 deaths (The Royal Society for the Prevention of Accidents, 2019). Accidents caused by the built environment hold a significant place among overall accidents and should be considered a major threat to user health. Therefore, it is essential to analyze and elaborate on accidents occurring within the built environment. Studies conducted on built environment-related accidents at both international and national levels generally focus on indoor accidents experienced by users in residential settings. In a study conducted by Ural & Gün (2008) in Türkiye, it was found that residential accidents account for 28.3% of all accidents, and moreover it was observed that:

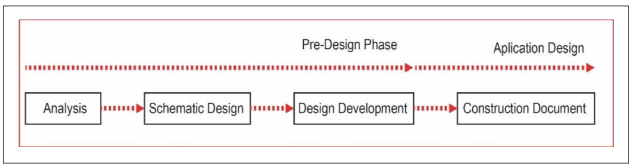

Figure 1. Traditional architectural design method phases (Dasgupta et al., 2019).

34.3% of residential accidents involve falls, of which 56.5% are falls from height and 43.5% are falls on flat surfaces.

Accidents involving burns in residences constitute 9.2% of the total, with 44.8% of these burns being attributed to building and building products (Ural & Gün, 2008).

In these studies, statistics related to disadvantaged user groups should also be defined when identifying user safety issues. In a study conducted by Bulgak et al. (2019), it was found that, as a disadvantaged group, 67.9% of elderly individuals encountered accidents within the built environment over the course of a year. In another study conducted with children, who represent another disadvantaged group, it was reported that 57.3% of children experienced domestic accidents (Gündüz & Aytekin, 2015). Studies on accidents experienced by users within buildings and their immediate surroundings have generally been conducted in the field of healthcare. However, efforts to solve these problems should not be limited to the healthcare domain; research should also be expanded and developed in the fields of user- architectural solutions. A literature review conducted on the Scopus database revealed the following findings:

- Out of 831 publications using the keyword "user safety," only 67 addressed architectural design and user safety.
- Out of 184 publications using the keyword "safe building," 108 focused on architectural design and user safety.

This analysis indicated that the publications predominantly dealt with topics such as fire safety, earthquake safety, disaster safety, and construction-work accidents. However, in addition to the risks mentioned, users frequently encounter everyday accidents within the built environment. The data analysis did not reveal any adequate or appropriate method proposals for preventing or reducing accidents through design management in this field. The primary cause of user accidents within the built environment is the mismatch between context, user, and design. To ensure that users are not exposed to the identified injuries, the buildings in which they spend a significant portion of their lives must meet the necessary standards. For these conditions and requirements to be fulfilled, buildings must be designed safely. To achieve safe design, potential risks that users may encounter during the occupancy period should be identified and addressed before and during the design process. The traditional design approach, based on knowledge and experience, and considering economic and social benefits, is insufficient for achieving this. In response to this need, initial efforts to reduce potential risks during the design process began in the fields of engineering and production. These initial phases were taken under the framework of "Prevention through Design." The emergence of the "Prevention through Design" system dates back to 1980, when the National Occupational Health and Safety Commission (NOHSC) initiated courses for engineering students that highlighted the role of design in enhancing safety (Creaser, 2008). The integration of hazard analyses and risk assessments forms the core of the safety-through-design concept (Manuele, 2008). The method, initially developed in the field of engineering design, has subsequently been applied in the field of architecture as well. Fundamentally, the method focuses on the distribution of responsibilities and the management of this distribution. In the architectural field, this system operates through the following phases respectively: completion of the design process, establishing the relationship between safety risks and preliminary controls in the design, integrating information through analyses, and implementing these elements during the design process (Yuan et al., 2019).

The "Building Safety Index," developed from the Prevention through Design method, was created as part of a research project initiated by the Tokyo School of Architecture (Ho & Yau, 2004). The method primarily utilizes a system of establishing a fundamental framework through expert opinion to identify safety risks. In prioritizing identified safety issues, the Analytical Hierarchy Process (AHP), developed by Saaty, is employed (Ho & Yau, 2004). The method is integrated with the "Building Health Index" within the project to contribute to guiding both the design and usage processes, ensuring that users can live safely and healthily in the building. However, the system tends to overlook multiple risk probabilities due to the hierarchical nature of the framework.

In contrast to the traditional design approach, in design management conducted with risk analysis in architecture, safety vulnerabilities can be accurately predicted (McDowell & Lemer, 1991). Risk analysis in the lifespan of a building should commence during the planning phase, and risk management should remain active throughout this period, with regular inspections contributing to the risk analysis. In the design of safe buildings produced through risk analysis, effective communication with stakeholders and project participants is crucial. Additionally, this method is a systematic process of planning, identification, analysis, evaluation, and resolution, supported by the appropriate monitoring, review, and documentation of the identified risks (HK OCSH - Development Bureau, 2019; McDowell & Lemer, 1991). In the safe building design process supported by risk analysis, designers can assess the risks users may encounter throughout the building's lifespan and can prevent or mitigate issues that may arise during usage activities through design, detailing, and planning. In the literature, there are many studies developed with an inductive approach based on sub-risks such as fire, earthquake, etc. in a piecemeal manner. However, while these studies produce fragmented solutions, they are incomplete in terms of the interaction of risks. A holistic approach that addresses user safety risks is needed.

Despite the presence of significant insights and approaches in the reviewed scientific literature, it has been observed that, within the Prevention through Design method, safety risk analyses are conducted post-design, whereby in the Building Safety Index approach, safety issues in design are defined through a generalized framework. Moreover, the sub-phases utilized in this method prove inadequate in addressing multiple and interrelated risk probabilities. However, in a design process that prioritizes user safety, there is a need for a comprehensive methodology that:

- Identifies factors that adversely affect user safety,
- Analyzes, evaluates, and prioritizes issues impacting user safety in and around the building during the pre-design stages,
- Resolves these issues through a defined safety framework.

Such a methodology must focus on these elements as specified, establish the necessary action phases in a correct sequence, guide the process with appropriate strategies, and facilitate informed decision-making. In this study, the "Integrated Risk-Oriented Design Method in Architecture" has been proposed as a structured approach to address these requirements. This study aims to develop an 'Integrated Risk-Oriented Design Method in Architecture' proposal.

In the developed method, risks are determined as a result of analyses and evaluations of the building and its built environment, occupant, function and obligation. This method is based on the deductive approach to identify all risks, which is designed to minimize risks in buildings. It is assumed that this method, which is intended to address risks in a holistic manner, will provide the grading of risks affecting user safety and guide the study of sub-risks.

MATERIAL AND METHODS

This method, which is deemed crucial for ensuring user safety in the built environment, has been developed using an inductive approach in the context of qualitative research. After an extensive literature review, factors negatively impacting users, potential risks they may encounter, and the adverse conditions these risks could create in the built environment were identified and classified. However, as the study aims to reduce user safety risks during the design phase, the risks addressed are limited to risks and risk derivatives specific to the design and pre- design stages. During the same process, potential approaches and phases that could be employed in the method's stages were identified, and the solution strategies for safe building design propositioned within the frameworks of Prevention through Design (PtD) and the Building Safety Index (BSI) were analyzed. Eventually, the method was formulated by grounding on these approaches. To assess the applicability of the formulated method, traditional design processes and architectural design circumstances were scrutinized. Data obtained from the literature review were integrated with the data of the conventional design practice and risk management insights. In the study, within the scope of risk management, a risk prioritization system was proposed which intends to resolve issues that risks may cause during the design phase, so that they are addressed before the users encounter them, and the Analytic Network Process (ANP), a comparative decision-making method developed by Saaty, was employed for this system. The core structure of ANP consists of a dynamic network configuration composed of clusters and interconnected nodes. Many decision problems cannot be structured in a purely hierarchical manner, as the interactions and dependencies between higher-level and lower-level elements must also be considered. The significance of criteria not only determines the priority of alternatives within the hierarchy but also influences the importance of criteria themselves. Feedback mechanisms facilitate the development of a roadmap to achieve the desired objectives, enabling the present to shape future outcomes (Saaty, 2006). The Analytic Network Process (ANP) analysis method, which is part of this approach, significantly contributes to the functionality of the system by addressing the interrelationships among criteria in the decision-making process and eliminating the need for a single-directional modeling approach in problem definition. Moreover, in this method resolved using the ANP system, the identification of multiple interrelated risk probabilities prevents the oversight of sub-group risks (Figure 2). Utilizing ANP during the decision-making process relieves modeling the problem as a network system, and during the modeling phase not only the relationships between the main criteria but also the internal impacts within them are taken into account (Ömürbek et al., 2013). Due to these features, ANP significantly contributes to determining the impact levels of risks in the prioritization of user safety issues that trigger one another within the built environment. In the study, the Super Decision software, specifically designed for such analyses, was utilized. The study primarily adopts an approach that integrates various existing techniques and further develops them into a practical and applicable form.

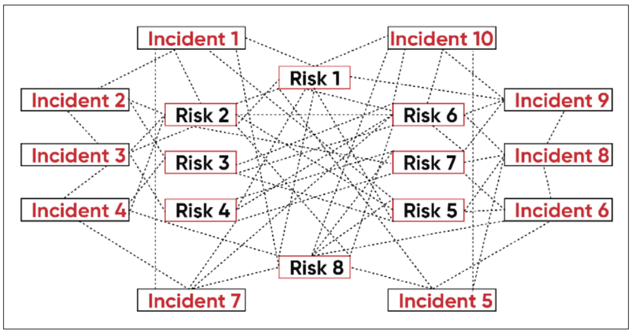

Figure 2. Risk and incident relation ANP flowchart (Saaty, 2006).

This study:

- Employs a qualitative research methodology in the stages of literature review and system development, and is non-manipulative,
- utilizes documentary and empirical methods as data collection techniques in the process of integrating documents, reports, and incidents;
- and, is an applied, Type 2 (method development) systematic research, as it aims to find a solution to an existing problem through design and development.

The flowchart of the research methodology is presented in Figure 3.

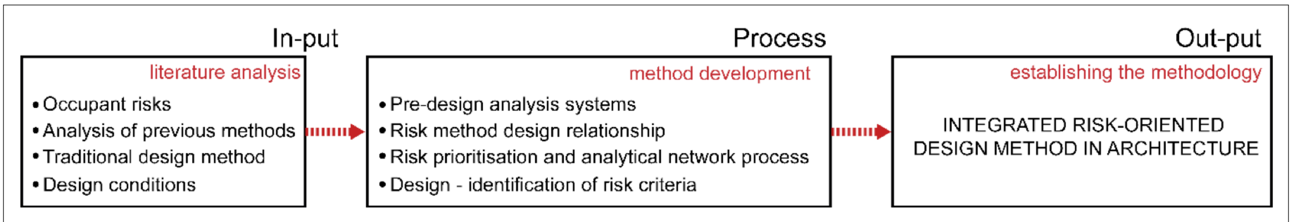

Figure 3. Research methodology flowchart.

INTEGRATED RISK-ORIENTED DESIGN METHOD IN ARCHITECTURE

In safe building design, risk management system is proposed to be integrated with the overall design process, and accordingly potential risks that could negatively impact user safety, along with the issues they may cause are intended to be identified and addressed during the early stages of the design process through an integrated risk management system. For the design outcome to be safe, the risk management process must be actively maintained throughout the entire design period. (HK OSHC - Development Bureau, 2019). In this sense, defined risks that users may encounter should be analyzed and evaluated by designers. The analysis and evaluation process, which forms the foundation of decision-making, must be effectively utilized to identify risks specific to design conditions. The risk-analyzed design method should fundamentally incorporate a robust analysis and evaluation process, and the results obtained from these analyses should be used to prioritize risks and establish risk parameters. During the design process, risk parameters should be integrated with standard design parameters to achieve a safe design. In the final design phase, the developed design should be brought to an executable level without altering the established risk priorities. The risk management process should remain active from the risk identification phase to the completion of the design, and during risk control, the entire process and the final design product should be assessed for user safety. In this method developed, tools such as Risk Management, the Analytic Network Process (Saaty, 2008) and the injury classes and their safety relationship created by Ozanne-Smith et al. (2008) are utilized, and by quantifying the safety criteria in the design process that is generally carried out with qualitative values, facilitating the development of accurate solution options was intended. The flowchart of the risk-oriented safe building design method is presented in Figure 4.

The core and most crucial phase of the proposed method is the analysis and evaluation process. The entire system and approach are built upon these analysis and evaluation phases. In the analysis process, the building's immediate surroundings, users, functions, and requirements should be examined. The conditions specified in Figure 5 are evaluated in these phases. The analysis phase includes the following sub-criteria:

Built Environment Analysis: Urban risk analyses and maps, city and neighborhood context analyses, access and accessibility maps, emergency routes, safety and physical condition assessments, and sociological and psychological analyses of surrounding users.

Occupant Analysis: Sociological analysis of building users (relationships with others), physiological analysis (age, gender, anthropometric characteristics, health status, mobility, substance and alcohol use, etc.), and psychological analysis (mental state, psychological disorders, etc.).

Function Analysis: Evaluation of the primary and secondary functions of the building, user capacity, and the presence of hazardous functions (such as nuclear, fire, explosion risks).

Obligation Analysis: Review of design standards, regulations, and codes applicable to the specific site, region, and country.

The data obtained from the analysis phase are transferred to the evaluation phase. In the evaluation phase, preliminary studies related to risks are developed, and the information is incorporated into the risk management process.

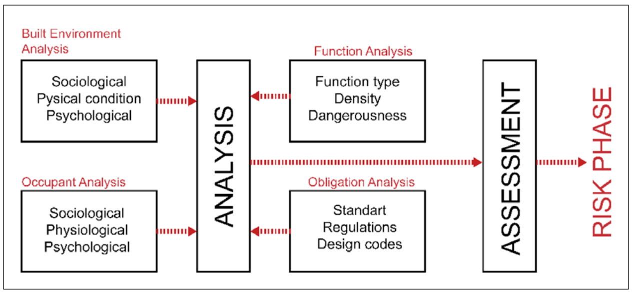

Figure 5. Analysis subsystems and evaluation.

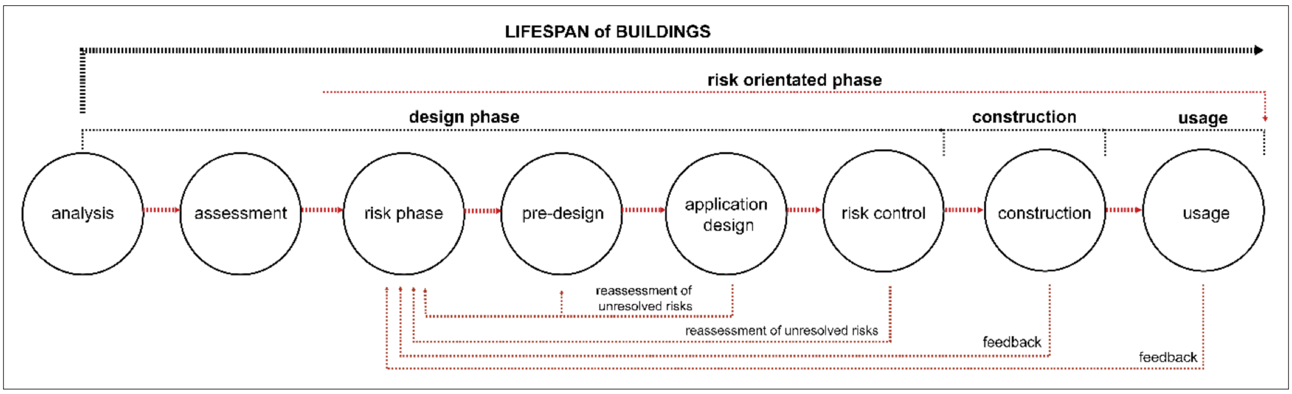

Figure 4. Risk – oriented design method in architecture flowchart.

Risk is measured in terms of the outcome or impact of the incident it may cause and the probability of its occurrence. Qualitatively, risk is evaluated in proportion to the expected losses if it causes an incident to occur and the likelihood of that incident occurring. Quantitatively, it is calculated by multiplying the probability of the incident by its potential outcomes (Misra, 2008). The risk analysis and evaluation process, which is part of the safe building design stages, is considered the most critical phase in ensuring safe building design (Ustaoğlu, 2020). In the process of managing safety, risk levels are rarely measured with absolute precision, and the levels of acceptability or thresholds that may pose safety concerns can only be determined through user consultations, expert consensus, scientific research, and public opinion surveys (McDowell & Lemer, 1991). This can be achieved by thoroughly identifying and analyzing potential risks in the pre-design phase and implementing measures to eliminate or mitigate them to low levels. The purpose of integrating the risk management process with the design process is to prevent the emergence of new risks and to minimize potential negative outcomes by avoiding existing risks.

To accurately assess risks with appropriate solutions, defined risks must be properly analyzed. For risks to be effectively analyzed, the risk factors must be correctly identified and integrated into a systematic framework. The risk process, which forms the foundation of the safe building design method, includes the identification of risks, analysis and evaluation of these risks, prioritization, and development of necessary solutions within the scope of risk management. For this analysis to be conducted accurately, it is essential to identify the factors influencing risk formation, the type and level of risk impact, and the design-specific risk acceptability level. This process involves recording potential future injuries identified in previous phases, defining risks that may pose safety issues, and conducting analysis and evaluation of these identified risks. In this phase, factors affecting risk identified in the previous process should be further developed and incorporated into the calculations. After determining the risk type and impact level, the potential outcomes and injury classes derived from these factors should be established and incorporated into the risk analysis phase.

The risk analysis phase involves identifying the injury class or classes of the risk, determining its probability, assigning a coefficient, assessing the impact level, and establishing a priority ranking. The risk analysis phase in safe building design should include the following principles (McDowell & Lemer, 1991):

It should employ a set of tools, methods, and procedures to characterize the threats posed by specific injuries.

In the absence of statistical data, expert, designer, and user opinions should be consulted to understand the likelihood of specific events occurring.

Criteria aimed at identifying the potential, injuries, and priorities of events that could lead to significant losses should generally be based on probability theory and statistical analysis principles.

Concepts such as health, safety, and property value should be taken into thoughtful consideration.

In buildings, users may encounter not only isolated injuries but also multiple or interconnected injuries that can be triggered during an incident. Additionally, when analyzed through specific examples, the same hazard may produce different impact probabilities for different user groups, such as severe harm (H2) for one group and serious harm (H3) for another. Therefore, each unique design should have its own specific risk management and risk analysis process. In this stage, where risk calculations are conducted, quantitative data are derived based on multiplying the probability of a hazardous incident by its potential outcomes. Hence, the possible damages and frequency of occurrence of incidents that may occur within the built environment must be identified. For this purpose, the table created by Ozanne-Smith et al. (2008) was utilized. The potential harm/impact classifications of injuries on users are outlined in Table 1.

The designer must evaluate the potential consequences and probabilities of harm classes that may impact users, in a design-specific manner, by considering the data derived from the analysis and evaluation phase along with the

Table 1. Harm classes and potential impacts (Ozanne-Smith et al., 2008)

	Class 1 – Major (H1)	Class 2 – Severe (H2)	Class 3 – Serious (H3)	Class 4 – Moderate (H4)
Potential Harm/Impact	Death	Stroke	Loss of a finger	Occasional severe discomfort.
	Permanent paralyses below the neck	Loss of hand or foot	Fractured skull	Chronic skin irritation
	Permanent loss of consciousness	Serious fractures	Severe concussion	Broken finger
	80% or more burn injuries	Serious burns	Serious puncture wound	Slight concussion
		Loss of consciousness for several days	Severe burns to hands	Moderate cuts to the face or body
				Severe bruising to body.

potential risks of the building's surrounding environment and function which are identified during the risk analysis process. However, due to the lack of recorded and published scientific data and statistics on accidents and their outcomes in artificial environments encountered by users, it is not feasible for experts to determine the level of these harm classes without employing a decision-making method. Therefore, utilizing the Analytical Network Process (ANP) and the Super Decision software in resolving this network structure that arises during the decision-making process concerning the determination of harm classes will significantly contribute to simplifying the studies. After defining the harm classes that the identified risks may cause, a network system should be established between the risks and damage classes and among the interrelated risks using the Analytical Network Process (ANP) developed by Saaty. This network system allows experts to make value comparisons on the formation of risks and their impact on other risks during the decision-making process. The scale developed by Saaty is derived from fundamental principles that include obtaining a functional equation as a necessary condition by generalizing continuous comparisons and then solving this equation in real and complex domains (Saaty, 2008). In this comparison scale, the formation probabilities of harm classes relative to each other are determined by assigning values based on the significance of the relationships between the criteria being evaluated. Saaty defined the degrees of importance as follows: 1 - equal or same importance, where both activities contribute equally to the goal; 3 – moderately more important; 5 – obviously more important; 7 – strongly more important; and 9 – extremely more important (Saaty, 2008). As an important phase in the analysis of risks, the establishment of the analytic network process for determining the probabilities of harm classes is defined through a sample study in the Super Decision software, using a comparative analysis of risks and harm classes as illustrated in Figure 6.

In the calculation of risks' harm and weighting classes, one of the harm and weighting classes defined as 10, 100, 1000, or 10000 is determined based on the levels obtained from the limit matrices, resulting from the comparative analysis of risks, the impact of risks on other risks, and harm classes using expert opinions in the Super Decision software.

After determining the harm and weighting classes of the risks, it is necessary to establish their impact levels. In the process of determining the risk impact levels, the number of individuals affected by the harm and the frequency of harm occurrence are also significant inputs. The higher the number of individuals expected to be affected and the frequency of occurrence, the higher the risk coefficient, leading to an increase in the risk impact level. The calculation of the risk coefficient is performed using the coefficients given in Table 2 and the Risk Hazard Coefficient Matrix specified in Table 3.

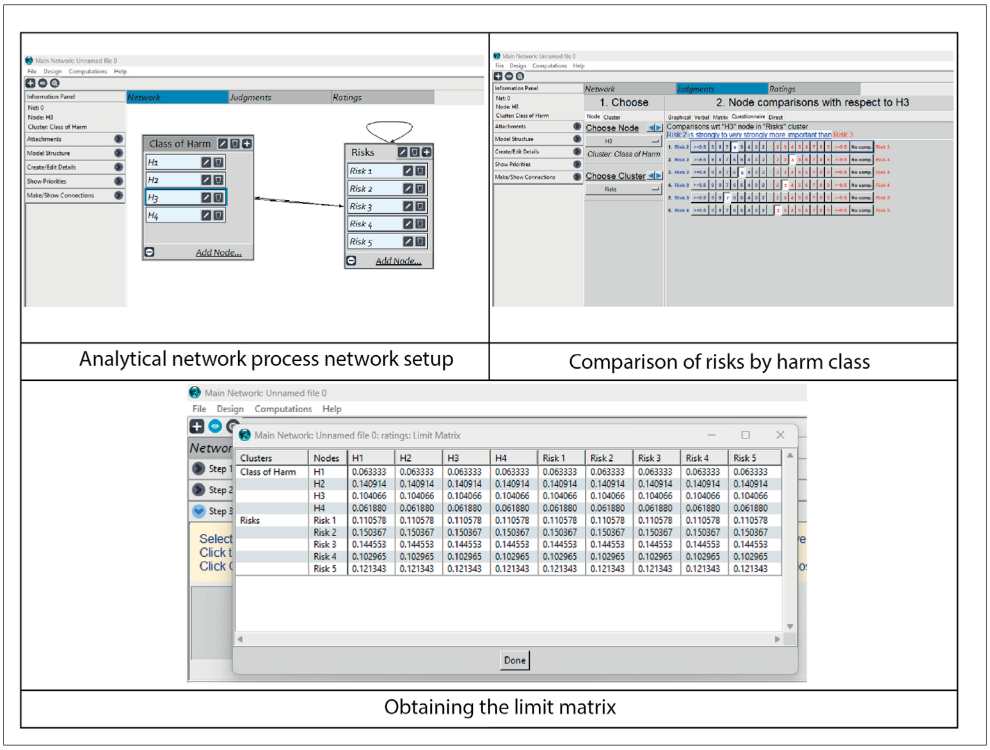

Figure 6. Obtaining comparative limit matrices of risks according to harm classes (adopted from Super Decision software).

Table 2. Table of coefficients for the number of individuals and the frequency of occurrence to be used in the risk coefficient calculation

	Number of Individuals	Number of Individual Coefficient		Incident Occurrence Frequency	Incident Occurrence Frequency Coefficient
Number of Individuals Impacted	5000 and over	6	Incident Occurrence Frequency	Once per month or more	6
	1000 - 4999	5		0 – 1 years	5
	500 - 999	4		1 – 4 years	4
	100 - 499	3		5 – 9 years	3
	50 - 99	2		10-19 years	2
	0 - 49	1		20 years and more	1

Table 3. Risk impact coefficient matrix (Slomka, 2005)

	Incident Occurrence Frequency						
	Level	1	2	3	4	5	6
Number of Individuals Impacted	1	1	2	3	4	5	6
	2	2	4	6	8	10	12
	3	3	6	9	12	15	18
	4	4	8	12	16	20	24
	5	5	10	15	20	25	30
	6	6	12	18	24	30	36

In the study conducted by Ozanne-Smith et al. (2008) to determine the risk impact level, the risk impact level is obtained by summing the results formed by multiplying the weighting class, risk hazard coefficients, and the probabilities of harm class occurrences. This calculation system is explained in Table 4.

By applying the calculation system developed by Ozanne-Smith et al. (2008) to all risk derivatives, the risk analysis results presented in Table 5 are obtained. Sorting these results from highest to lowest enables the identification of risks that need to be addressed, are acceptable, unacceptable, or need to be monitored.

Integrated risk analysis involves estimating the timeframes in which potential scenarios may occur after clearly identifying possible event chains that could lead to fatalities, injuries, and other losses, following the determination of risks, their dimensions, impact levels, and priorities (McDowell & Lemer, 1991). In the risk analysis phase, after determining the priority ranking of risks, the solutions to be developed in response to the dimensions of the risks and the processes that need to be improved must be identified and evaluated during the risk assessment process. In the risk assessment phase, a method of evaluation should be developed where there is a flow from high-impact risks to low-impact risks. Upon completion of the evaluation, the process moves to the creation of risk parameters. By establishing risk parameters, the general constraints of the design are defined, and the design process begins. The flowchart for analysis, evaluation, and risk process in safe building design is shown in Figure 7.

In the preliminary research phase of the design methodology in safe building design, analyses and evaluations are conducted to collect data for the risk process. The design process in safe building design is a convergence of the standard design management process and the risk process, where safety concerns and design criteria are integrated. In this process, data such as user characteristics, ergonomics, spatial and environmental features should be considered in conjunction with safety criteria. Based on the data obtained from the analysis and evaluation phases, the factors affecting the risk, the levels of exposure to the risk, and harm classes are identified, and risks are prioritized to develop necessary solution strategies. A roadmap is created to define the scope of the design and design decisions. Following these

Table 4. Risk impact score calculation table (Ozanne-Smith et al., 2008)

Risk Impact Score Calculation						
Harm and Weighting Class		1/ Risk Impact Coefficient		Harm Class Likelihood		Product
10000	÷	1/ Coefficient	x	% Class1	=	P1
1000	÷	1/ Coefficient	x	% Class2	=	P2
100	÷	1/ Coefficient	x	% Class3	=	P3
10	÷	1/ Coefficient	x	% Class4	=	P4

Hazard Score: P1+ P2+ P3+ P4.

Table 5. Integrated risk analysis

Risks	Risk Origins	Possible Consequences	Harm Classes	Risk Impact Scores
R1	RO1	O1	H1 – H2 – H3 – H4	PA
R2	RO2	O2	H1 – H2 – H3	PB
R3	RO3	O3	H2 – H3 – H4	PC
R4	RO4	O4	H3 – H4	PD
R5	RO5	O5	H4	PE

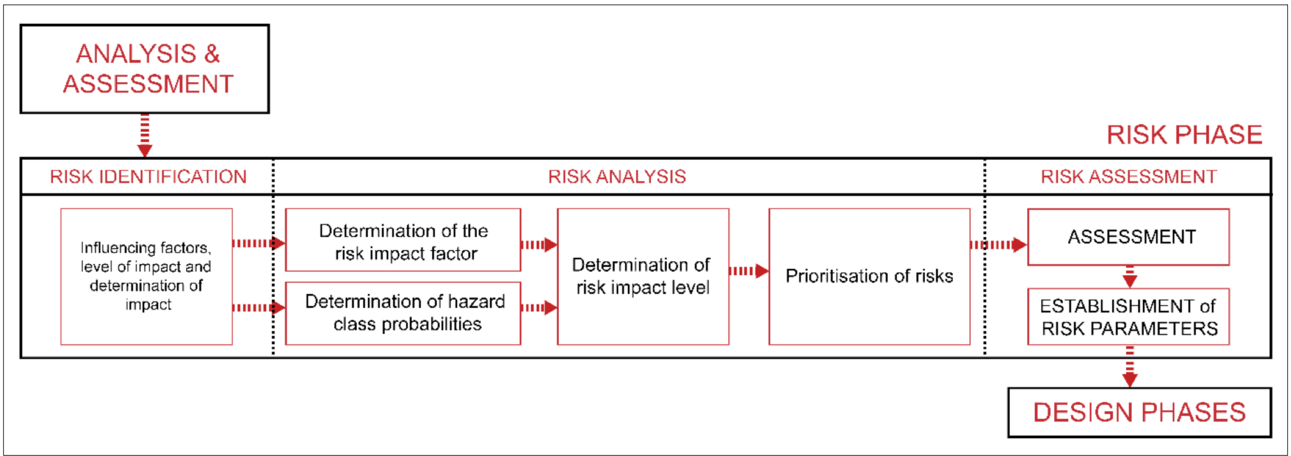

Figure 7. Analysis, assessment, risk and design phases in safe building design.

phases, it is important to share the process with the user, conduct post-design risk assessments, and address any identified issues in collaboration with the user. If no safety issues are found during the process, the design phase can be considered as completed (Figure 8).

The construction process of the building whose design is completed should also incorporate similar concerns. After the design phase of the risk-oriented building is finalized, its production should be carried out in accordance with the design specifications. Risk monitoring should remain active during the production phase as well. Design experts must continue their supervision to ensure that the production process is conducted under appropriate conditions. The method aims to provide the highest possible level of solutions to safety issues that users may encounter in and around the building throughout the occupancy period. Additionally, feedback should be collected from every design created with the contribution of the method during the occupancy phase, influencing the development of future designs. To facilitate this feedback, "Post-Occupancy Evaluation" and "Evidence-Based Design" methods should be utilized during the occupancy phase. During use, the safety evaluation of the designed building is conducted using the Post-Occupancy Evaluation method (Fay et al., 2016).

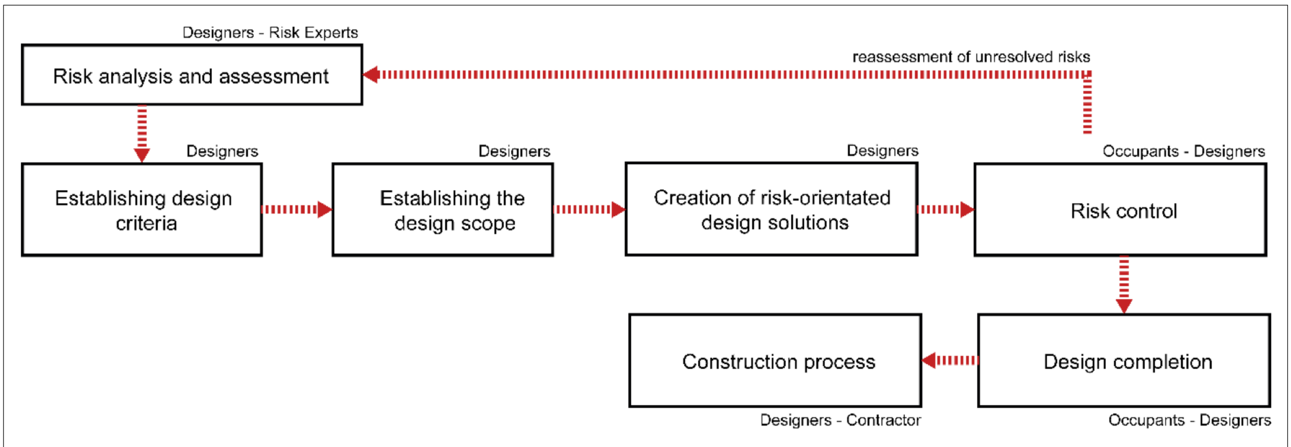

Figure 8. Design process in safe building design.

Evidence-based design incorporates a system that involves the user in the decision-making process, relying on the most accurate information obtained from reliable research and project evaluations. The method includes post-occupancy evaluation, and the information obtained from this process is used to enhance the design process. Evidence-based design is defined as a process that, by leveraging the most accurate experiences obtained throughout the process, reaches rational and practical solutions in collaboration with the user (Hamilton, 2003). The Safe Building Design Method is supported and developed through evaluations conducted using the Evidence-Based Design method (Fay et al., 2016) In risk- oriented building design, identified risks and risk solutions should be stored in a risk pool. The implemented solutions should be reviewed during the building occupancy phase using the Post-Occupancy Evaluation method and then transferred to the evidence-based design system. The data obtained from the evidence-based design system should be fed back into the risk pool to support future designs with system feedback. The flowchart of the integrated Risk-Oriented Building Design, Post-Occupancy Evaluation, Evidence-Based Design, and Risk Relation System is shown in Figure 9.

Risk Prioritization with Integrated Risk-Based Design Method in a Primary School Case Study

The region, area, or function of the case study of the research was not selected according to specific criteria. Within the scope of the study, the risk prioritization section of the proposed risk-oriented integrated method was examined. This examination was limited to 21 sample risks obtained from the analysis and evaluation phases related to the building's immediate surroundings, users, and function. The basis of this limitation is the validation of the risk prioritization working system. The harm classes of the defined risk types were determined. Factors such as the building's surroundings, number of users, user types, user behavior, and building function were analyzed for the risks with defined harm classes. In this context, a network system for risks and harm classes was defined in the Super Decision software, and comparative analyses were conducted. As a result of the calculations, numerical values of the risk impact levels

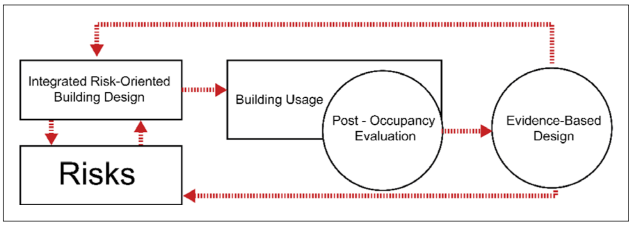

Figure 9. Integrated risk-oriented building design, post-occupancy evaluation, evidence-based design and risk relation.

were obtained. Based on these results, threshold values for risk impact levels that need to be addressed and controlled in design were determined (for this design, values of 2000 and above were defined as high risk, values between 1000 and 2000 as moderate risk, and values of 1000 and below as low risk)

The case study of the developed method was conducted on an educational building designed as a primary school for the residents of the Mimar Sinan Neighborhood in Sultanbeyli District, Istanbul. According to official regional statistics, the socio-economic status of Mimar Sinan Neighborhood is classified as C-D, with the majority of the population having completed primary or secondary education. The fear of crime is at a moderate level (Bilen et al., 2013), the average number of children per household is 3, and the majority of the population falls within the 0-44 age group. In the primary school building, 500 students, along with 30 teachers and administrative staff, are considered regular users, while 100 parents visiting the building daily are classified as transient users. Based on the data obtained from the analyses, potential risks arising from the building's immediate surroundings, users, and potential consequences of incidents related to the building's function and design have been addressed within the study's scope limitations before the design process. In this context, Table 6 outlines the risk origins, risks, and the harm classes that these risks may cause. After calculating the harm classes, the number of individuals affected, frequency of occurrence, and harm class probabilities of the identified risks according to the developed method, the risk impact levels were calculated, and the results are presented in Table 7.

As a result of the data obtained from the research, the following risks have been prioritized in terms of their importance: earthquakes, fire, incompatibility of the design with user behavior and number of users, risky active nature of the students due to their age, low safety and accident awareness among students, design and product decisions that disrupt the visual-cognitive process in spaces and building elements, and the selection of building products that are unsuitable for users. These issues are identified as safety concerns that need to be addressed in priority in the design process.

The following have been identified as moderate risks required to be resolved: low accident awareness among students, the presence of users from different age groups and with varying anthropometric characteristics, the active nature of children, low safety awareness in the surrounding social environment, lack of safety, accident, and harm awareness among students, flood risk in the region, moderate fear of crime in the community, mismatch between spaces/building elements and user anthropometry, and students' inclination towards exploration. Whereas the following have been identified as low-level risks: inadequate lighting forms that disrupt the

Table 6. Limited risks and harm classes in the educational building

Risk No	Risk Origins	Risks	Harm Classes
R1	RO1	Located in a 1st-degree earthquake zone (İBB Deprem ve Zemin İnceleme Müdürlüğü, 2009) (Istanbul Metropolitan Municipality Directorate of Earthquake and Ground Research)	H1 – H2 – H3 – H4
R2	RO1	It has moderate level flood risk (İBB Deprem ve Zemin İnceleme Müdürlüğü, 2009) (Istanbul Metropolitan Municipality Directorate of Earthquake and Ground Research)	H2 – H3 – H4
R3	RO1	Marked as precautionary settlement areas (İBB Deprem ve Zemin İnceleme Müdürlüğü, 2009) (Istanbul Metropolitan Municipality Directorate of Earthquake and Ground Research)	H2 – H3 – H4
R4	RO1	High crime rates in the area and the community's tendency towards harmful behavior (Bilen et al., 2013)	H3 – H4
R5	RO1	A society with low safety awareness due to low educational level, consciousness, and awareness in the social environment (Endeksa, n.d)	H2 – H3 – H4
R6	RO1	A society with a moderate fear of crime (Social environment prone to criminal behavior) (Bilen et al., 2013)	H2 – H3 – H4
R7	RO1	Unplanned and disorganized built environment (Şatıroğlu, 2012) A society prone to exhibiting anomalous behavior	H2 – H3 – H4
R8	RO2	A user profile with low safety perception and awareness due to inadequate family education and involvement (WHO, 2015)	H1 – H2 – H3 – H4
R9	RO2	Inadequate accident and safety perception among users due to low socio-economic family background (Şahiner et al., 2011)	H1 – H2 – H3 – H4
R10	RO2	Users from different age groups and with varying anthropometric characteristics	H2 – H3 – H4
R10	RO2	Active nature of children (Kapısız & Karaca, 2018)	H2 – H3 – H4
R11	RO2	Children's low perception of accidents	H2 – H3 – H4
R12	RO2	Children's tendency to play with potentially harmful materials (Templer, 1992)	H1 – H2 – H3 – H4
R13	RO2	Children's inclination towards exploration	H2 – H3 – H4
R14	RO2	Lack of safety, accident, and injurious awareness in children	H2 – H3 – H4
R15	RO3	Evacuation problems during emergencies due to the mismatch between the size and number of escape areas and the number of users	H1 – H2 – H3 – H4
R16	RO3	Insufficient spatial area relative to the number of users	H2 – H3 – H4
R17	RO3	Design implementation and product usage decisions in spaces and building elements that disrupt the visual-cognitive process	H1 – H2 – H3 – H4
R18	RO3	Use of inadequate lighting forms in buildings that disrupt the visual-cognitive process	H2 – H3 – H4
R19	RO3	Mismatch between spaces and building elements and user anthropometry	H2 – H3 – H4
R20	RO3	Selecting unsuitable products in building (Maleque & Salit, 2013)	H2 – H3 – H4
R21	RO3	Fire risk (Kılıç, 2003)	H1 – H2 – H3 – H4

Immediate Surrounding Originated: RO1 – User Originated: RO2 – Function Originated: RO3.

visual-cognitive process, an unplanned and disorganized built environment, being in a precautionary settlement area, high crime rates, and a social environment with a high tendency toward harmful behavior.

The case study highlights that the lack of standards and location-specific safety measures set by regulations and requirements leads to insufficient precautions and the inability to develop appropriate safety solutions for users. It is determined that safety risks should be examined in a location-specific and design-specific manner, and necessary solutions should go beyond existing regulations and requirements.

Table 7. Risks and risk impact score calculation results

Risk No	Risk Origins	Harm Classes	Risk Impact Scores
R1	RO1	H1 – H2 – H3 – H4	14786.77
R21	RO3	H1 – H2 – H3 – H4	12568.85
R15	RO3	H1 – H2 – H3 – H4	10563.75
R12	RO2	H1 – H2 – H3 – H4	9518.04
R9	RO2	H1 – H2 – H3 – H4	9025.20
R8	RO2	H1 – H2 – H3 – H4	6175.68
R17	RO3	H1 – H2 – H3 – H4	5632.04
R16	RO3	H2 – H3 – H4	3688.07
R20	RO3	H2 – H3 – H4	2156.65
R11	RO2	H2 – H3 – H4	1799.48
R10	RO2	H1 – H2 – H3 – H4	1688.18
R10	RO2	H2 – H3 – H4	1367.89
R5	RO1	H2 – H3 – H4	1288.62
R14	RO2	H2 – H3 – H4	1225.65
R2	RO1	H2 – H3 – H4	1160.48
R6	RO1	H2 – H3 – H4	1158.66
R19	RO3	H2 – H3 – H4	1158.66
R13	RO2	H2 – H3 – H4	1036.66
R18	RO3	H2 – H3 – H4	876.22
R7	RO1	H2 – H3 – H4	845.02
R3	RO1	H2 – H3 – H4	656.75
R4	RO1	H3 – H4	465.77

CONCLUSION

Design is a system that encompasses parameters such as the analysis phase, suitability to location, occupant and function, ergonomics, accurate design and product decisions, and requires taking multi-criteria into consideration in decision-making. Safe building design aims to ensure occupant safety by integrating the design process and risk management system. The process is based on risk analysis and assessment steps. In this context, the built environment of the building, occupant, function and obligation are analyzed; risks are identified, evaluated and prioritized with the data obtained. Risk analysis involves calculating hazard results and probabilities by determining risk harm classes and probabilities of occurrence. In this process, decision making is supported by using tools such as Analytical Network Process (ANP) and Super Decision program. Risks are classified according to their impact levels and solutions are developed in order of priority. Possible harm classes include varying negative impacts and risk parameters are created with expert assessments. All these processes aim to control risks and ensure safety throughout the design process. The integration of analysis, assessment and risk processes in safe building design provides a design-oriented system that ensures occupant safety. Post-design risk auditing and building occupant feedback are supporting elements of the process. Testing the proposed method through case studies has confirmed that the data obtained supports the suggested method. Additionally, this system provides significant contributions and greatly enhances the process by evaluating design-specific processes in the context of location-specific designs. By developing solution proposals according to the priority order of risks and resolving problematic situations through the risk analysis system, it provides a roadmap for the designer and ensures that users can live more safely and healthily within the building.

It is believed that if the proposed method is correctly applied, location-specific solutions can be developed in building production worldwide. This method aims to identify and address safety issues that users may encounter during the design process through design-specific solutions, thereby eliminating or minimizing problems that negatively impact user health and result in loss of life and property. Functioning as an integrated system throughout the production and usage phases, this method, when combined with healthy building practices, will provide safe and healthy buildings that meet user needs. It is anticipated that supporting the method with statistics, scientific studies, and robust regulations will guide the development of safe building design methodologies.

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