UDC: [005.334:550.34]:[725.1:614.21](497.742)
Original scientific paper

NONSTRUCTURAL SAFETY OF HOSPITALS FOR DISASTER: A CASE STUDY OF PHI ''GENERAL HOSPITAL'' STRUMICA

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Abstract

Hospital complexes or buildings are specialized and complex facilities primarily designed to provide healthcare services. They are expected to function as safe and operational environments before, during, and after seismic events or other disasters, ensuring the continuity of medical care and emergency response. Hospital safety implies the highest possible level of protection for all healthcare facilities, regardless of the level of complexity of the functions they perform. However, the complexity of hospital facilities, the utilization of their capacities, the specific equipment they possess, and the built-in installations can significantly compromise hospital safety. These factors increase hospitals' vulnerability across multiple dimensions: the structural system; the non-structural system—including architectural elements, infrastructural protection and accessibility, critical systems, installations, equipment, and reserves and administrative aspects such as spatial organization of space, functions they perform, personnel, etc.
This study analyzes the second component contributing to the vulnerability of the hospital complex—the non-structural safety of the PHI "General Hospital" Strumica, with a focus on the 'Main Building' as the central facility based on the Hospital Safety Index as the chosen measurement tool. This building is the largest in terms of surface area and accommodates the majority of the hospital's functions. As part of the analysis process, an assessment of the non-structural elements—including architectural components, infrastructural protection and accessibility, critical systems, installations, equipment, and reserves—was conducted and presented, specifically for the Main Building.
Considering the fact that damage to non-structural elements in a hospital complex or facility can significantly increase the risk of loss of human life, destruction of equipment and property, and functional disruptions to the facility as a whole, it is essential to carry out an evaluation and assessment of the current condition of these elements. The primary goal of this assessment is the development of medium and long-term national policies and regulations that will ensure hospital safety in the event of disasters.

Keywords: hospital, vulnerability, non-structural elements, risk, disasters.

1. Introduction

With the intensification of the development process in the Republic of North Macedonia, the expansion of urban areas, increased rural-to-urban migration, and the country's classification as moderately prone to earthquakes, the reduction of non-structural vulnerability has gained growing attention from both the relevant institutions and the general public.
In addition to the damage caused to urban areas and existing infrastructure, disasters can seriously affect hospitals and their non-organizational components. Hospitals, as the first line of medical service provision during and/or after a natural disaster, must maintain their stability, ensure the safety of their patients and staff, and continue operating without interruption, as they would under normal conditions (Basiri, 2024).
As a consequence of seismic activity, it often happens that it causes insignificant damage to the structural system of a healthcare facility, yet its function is disrupted due to the damage that may be suffered by the non-structural elements of the facility.
Considering the fact that damage to non-structural elements in an existing healthcare facility not only increases the risk of loss of human life but also results in an average financial cost

https://doi.org/10.62792/ut.jas.v11.i21-22.p3073

estimated, according to existing research, at approximately 85–90% of the facility's total value (Krauskopf & Saavedra, 2004), it becomes essential to assess the non-structural safety of the hospital building. This should be done through a detailed evaluation of all non-structural elements within the system.

Previous experiences has shown that, in general, little attention is paid to non-structural elements in seismic designs of structures, to the extent that codes for aseismic design do not include standards for non-structural elements. In the territory of the Republic of North Macedonia, experiences from past earthquakes have shown that structures designed in accordance with current aseismic design standards have proven to be good, in contrast to the poor response shown by non-structural elements (Milutinovic, Trendafiloski, & Olumceva, Disaster preparedness planning for small and medium size hospitals based on structural, nonstructural nad functional vulnerabillity assesment, 1995).

Frequently, secondary effects caused by damage to non-structural elements can significantly worsen the situation. In some cases, non-structural defects can contribute to the occurrence of a structural defect (Milutinovic, Trendafiloski, & Olumceva, Earthquake related emergency response of a large hospital campus in the Republic of Macedonia, 1998).

Therefore, it is necessary to assess the non-structural safety of the elements in the system and their readiness to respond in a crisis situation in order to ensure that they can function acceptably in critical conditions.

This study provides a detailed overview of the analysis and assessment of the non-structural elements of the hospital complex PHI “General Hospital” Strumica, with a focus on the Main Building. Using the Official Assessment Form for Non-Structural Safety Level of Non-Structural Elements, derived from the Official Hospital Safety Index (C3O, 2015), an evaluation of the current condition of these elements was carried out. The results are presented along with a detailed bill of quantities and cost estimation for the architectural/construction components of the building. Additionally, an analysis was conducted to estimate the non-structural cost for the restoration or replacement of each category of the reviewed non-structural elements.

2. Analysis and Assessment of the Non-Structural Elements of the 'Main Building' at the PHI “General Hospital Strumica”

The "Main Building" of the hospital complex PHI "General Hospital" Strumica, built in 1970, is a central building and the largest in terms of area compared to the other six buildings within the complex, housing most of the functions of the hospital (**Figure 1**). It contains four departments, six clinics, an X-ray service, and other services that are functionally interconnected through hot links. From a structural point of view, the building is constructed with a reinforced concrete frame and infill made of reinforced concrete, consisting of five floors above ground (G+4) (**Table 1**).

The "Main Building" is the most frequently visited and used facility within the complex, with around 166 employees/patients passing through on a daily/nightly basis, according to interviews conducted with the staff. Additionally, approximately 305 users pass through the building on a transit basis (**Table 1**).

Figure 1. Location of the PHI "General Hospital" Strumica (Main building highlighted)

Figure 2. On-site photo of the Main Building within the "General Hospital" Strumica, orientation northeast (NE)

Table 1. Main Building Profile – PHI 'General Hospital' Strumica

Building	Construction system	Building height above the ground	Number of users (day/night)
Main building	Reinforced concrete frame	G+4	307

In order to determine the level of non-structural safety of the "Main Building," this study analyzes four categories of non-structural elements that are part of the "Main Building," specifically:

1. Architectural elements
2. Infrastructure protection, access and security
3. Critical systems
4. Equipment and reserves

For all categories of non-structural elements that constitute the building, reports provided by the competent authorities—specifically the existing architectural plans of the building—were collected and reviewed. A comprehensive on-site visual inspection was conducted by the author. Using an Official form derived from the Hospital Safety Index (СЗО, 2015), which is

specifically designed to assess the level of non-structural safety of such elements, the current condition of these elements, for the purpose of this study was carefully evaluated.

2.1 Architectural safety of the "Main Building"

The first category of non-structural elements within the “Main Building” are the architectural elements that are essential for the functionality of the building despite not being part of the load-bearing system (Organization, 2000). They include: doors, windows, shutters, floor coverings, elevators, external and internal walls, roof structure. For the purposes of this study, using the Official Form for assessing the level of non-structural safety of non-structural elements taken from the Hospital Safety Index (Кочубовски, Зисовска, Милутиновиќ, & Софрониевска-Главинов, 2017) an assessment of the current state of each of the listed elements individually was given, according to the visual inspection on field (**Table 2**).

Table 2. Assessment of Non-Structural Safety Level of Architectural Elements

Architectural Safety of the Main Building	**Safety Level (2024)**		
	Low	**Moderate**	**High**
Windows			✓
Doors			✓
Floor coverings			✓
Elevators		✓	
Internal walls	✓		
Roof structure		✓	

The results presented in **Table 2** indicate that the windows are in good condition (high safety level). They are relatively new and have been partially replaced through institutional funds and donations. There is little to no likelihood of damage that would compromise their functionality or that of other elements, systems, or functions within the building.

The doors are also in a good condition (high safety level), relatively new, with partial replacement carried out using internal funds and donations. They show a low probability of damage affecting their operation or that of other systems. Furthermore, their width complies with the prescribed architectural design standards (Neufert, 1970).

The floor coverings are in good condition (high safety level) and do not interfere with the current functioning of the building.

As for the stairwells in the "Main Building," they are reported to be in good condition. However, the three elevators—one transport, one for patients, and one for food—are often non-functional. This causes significant operational challenges and, therefore, the elevator system has been assigned a moderate safety level.

The interior (partition) walls are in poor condition (low safety level). They are prone to damage, which could interfere with the functioning of other building components. Many of the wooden partitions are movable, and visible damage has been observed, limiting their usability.

The roof structure is assessed to have a moderate safety level. Although it is vulnerable to damage, such damage would not significantly impact the performance of other systems or functions within the facility.

In parallel with the evaluation of the existing condition in which the architectural elements in the Main Building are located, the author prepared a construction and cost estimate for the architectural/construction components of the building (**Figure 3**).

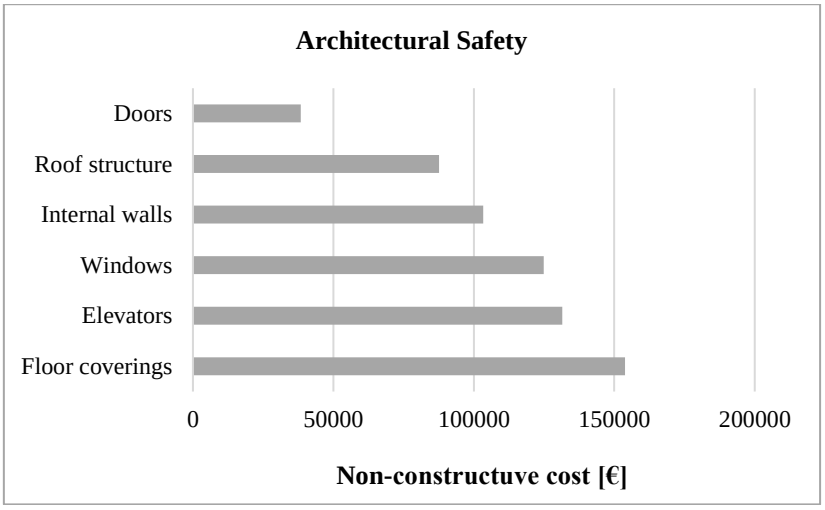

Figure 3. Cost Analysis of Non-Structural Architectural Elements

The results obtained (**Figure 3**) indicate that the highest non-structural costs for replacement, repair, or rehabilitation are expected for the floor coverings of the "Main Building," with a total estimated cost of approximately 153,776€, based on current market prices in the Republic of North Macedonia.

2.2 Infrastructure protection, access and security

Infrastructure protection, access and safety to/from and within the facility is the second category (Pan American Health Organization, 2000) based on which the non-structural elements in the "Main Building" facility were analyzed. It refers to an assessment of the existing road and pedestrian infrastructure around the hospital, taking into account the fact that good infrastructure enables the smooth functioning of the hospital during and after emergencies and disasters.

Table 3 provides an assessment of the level of non-structural safety of the road and pedestrian infrastructure as key elements of the category: Infrastructure protection, access and safety.

Table 3. Assessment of Non-Structural Safety Level of Infrastructure protection, access and security

Infrastructure protection, access and security	**Safety Level (2024)**		
	Low	**Moderate**	**High**
Road and Pedestrian Infrastructure			✓

The results shown in **Table 3** show that the existing infrastructure has been rated as having a high safety level. There is little to no probability of damage occurring to it within or around the hospital, and it is not expected to hinder the operation of other elements, systems, or functions of the hospital complex under emergency conditions.

The evaluation of the current condition of the existing road and pedestrian infrastructure is presented in **Figure 3**, which also includes a cost analysis of the indicated non-structural elements.

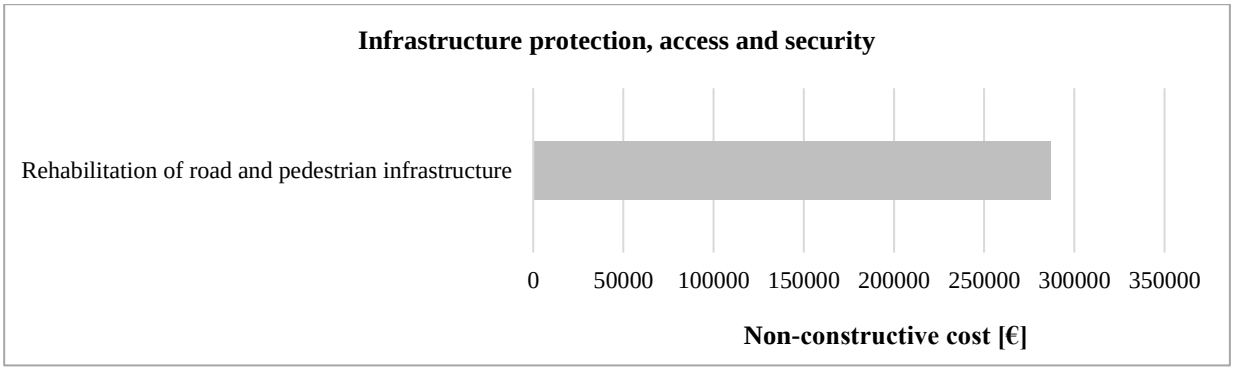

Figure 4. Cost Analysis of Non-Structural road and pedestrian infrastrucure

The results (**Figure 4**) indicate that the highest estimated non-structural cost for replacement, repair, or rehabilitation of the existing road and pedestrian infrastructure within the hospital complex is 287 049€, based on current market prices in the Republic of North Macedonia.

2.3 Critical systems

The main focus of the Critical Systems category is the safety, capacity, operational management, preventive maintenance and recovery of critical systems for the functioning of the hospital during and immediately after emergencies and disaster. Critical systems include: electrical installations, telecommunications systems, water supply, fire protection, waste management, fuel storage, medical gases in cylinders, heating, ventilation, and air conditioning (HVAC) systems (СЗО, 2015). Although the collapse of one or more critical systems may not threaten the structural stability of the building, they can lead to the cessation or disruption of the functioning of the hospital and thus can greatly endanger people as users of the space, causing damage to other parts of the hospital building.

Table 4 presents an assessment of the condition, safety, and stability of the critical systems in the "Main Building" facility, conducted using the official Hospital Safety Index template (Кочубовски, Зисовска, Милутиновиќ, & Софрониевска-Главинов, 2017).

Table 4. Assessment of Non-Structural Safety Level of Infrastructure protection, access and security

Critical Systems	**Safety Level (2024)**		
	Low	**Moderate**	**High**
Electrical systems (generators)	✓		
Electrical installation	✓		
Telecommunications systems			✓
Water supply systems		✓	
Fire protection systems		✓	
Waste management system			✓
Fuel tanks			✓
Medical gases in cylinders	✓		
Fuel oil tank	✓		

Heating with radiators			✓
Air conditioners			✓

The visual inspection on site showed that within the hospital facility there is only one electric generator with a total capacity of 50KW that runs on oil and covers the needs of only critical points, the operating blocks in the hospital complex are connected to it, while the rest of the hospital is not covered. The facility does not have an alternative energy source, and the existing generator covers less than 30% of the demand, which is why it is rated as having a low safety level according to the Hospital Safety Index.

The electrical installation in the facility is old and dilapidated with a large number of unprotected extension cables and unsecured lines, which is why it is rated as having a low safety level.

The telecommunication systems are in good condition, well secured and do not cause any interference in hospital communication, resulting in a high safety level rating.

Regarding the water supply systems, the hospital has water reserves with a capacity of 45,000 liters for more than 72 hours, with medium security of the water supply system rated at a medium safety level. There are no procedures for their maintenance and measures need to be taken for their rehabilitation.

The hospital does not have a fire and smoke detection system. There are only fire protection devices, which are not sufficiently secured, some of them are non-functional. The hospital has documents for maintenance and inspection, but there are no maintenance procedures. They are rated at a moderate safety level.

The waste management system is rated at a high safety level. The hospital also has documented procedures for maintaining the hospital's waste management system in emergencies that it applies in its current operation.

The hospital has its own oil tanks with sufficient capacity for more than 72 hours with a capacity of 45,000 liters, properly placed in a safe place.

Regarding the medical gases in cylinders available at the hospital, the visual inspection on site showed that although they are in the existing function of the facility, the selected premises for storing medical gases in cylinders do not meet the prescribed standards (Службен весник на РМ, бр. 26, 2009) and are at high risk due to the lack of protective measures and difficult accessibility, which makes ongoing maintenance difficult. It is rated at a low safety level.

In parallel with the assessed safety and security of the critical systems using the official Hospital Safety Index template (Кочубовски, Зисовска, Милутиновиќ, & Софрониевска-Главинов, 2017), at **Figure 5** results obtained from the prepared construction cost estimate for the renovation and rehabilitation of the listed non-structural elements are shown.

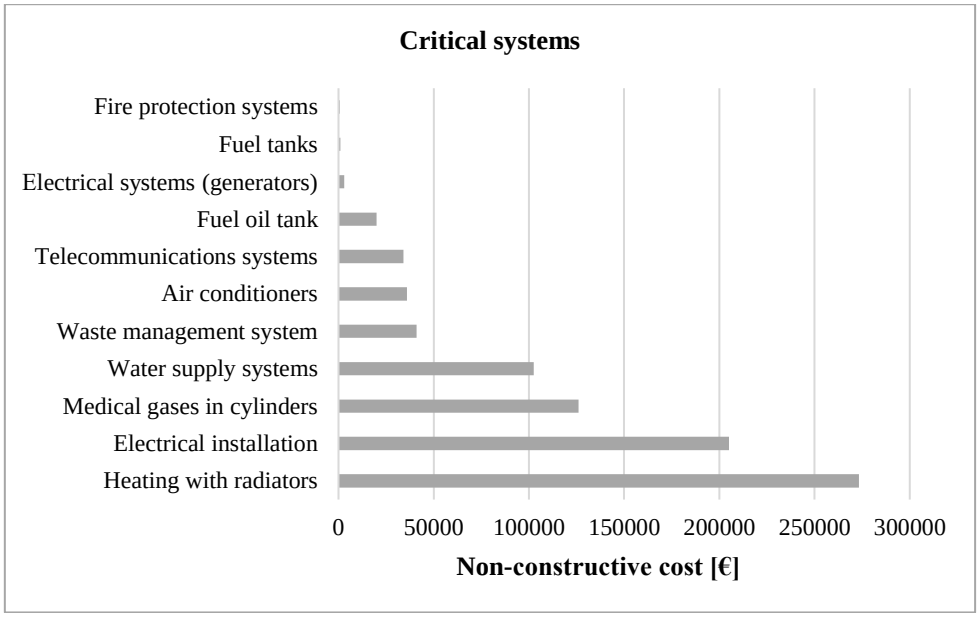

Figure 5. Cost Analysis of Non-Structural cost of Critical Systems

The results obtained from the prepared construction bill of quantities show that the highest non-structural costs for replacement/repair/rehabilitation of critical systems in the Main building are expected for the heating units with a total cost of approximately 273,380€ based on current market prices in the Republic of North Macedonia.

2.4 Equipment and Supplies

In their daily functioning, the medical and technical staff in the hospital use a wide range of equipment (medical, diagnostic, office), non-clinical conditions and consumables in order to provide conditions for adequate treatment of patients and perform critical activities within the hospital facility (СЗО, 2015).

Equipment and supplies as the fourth category (Pan American Health Organization, 2000) non-structural elements in the "Main Building" facility are divided into two subgroups: furniture and office equipment: tables, chairs (static and mobile) and medical and laboratory equipment used for diagnosis and treatment, graphically shown in **Table 5**.

What is important to mention is that the capacity to carry out health activities in the "Main Building" facility as a secondary health facility is directly dependent on the availability and supplies of consumables, in order to continuously and uninterruptedly use health care.

Table 5. Assessment of Non-Structural Safety Level of Equipment and Supplies

Equipment and Supplies	**Safety Level (2024)**		
	Low	**Moderate**	**High**
Tables		✓	
Chairs		✓	
Beds			✓
Equipment and furniture in the laboratory			✓

The results obtained from the evaluation of the non-structural elements in the hospital building "Main Building" based on the classification established in the Hospital Safety Index developed

by the Pan American Health Organization (PAHO) and the World Health Organization (WHO) (Organization, 2000), (C3O, 2015).
show that a large part of the equipment and furniture (tables, chairs) in the "Main Building" building is old and dilapidated, in poor condition and needs to be replaced.
Some of the old beds have been replaced with new ones through donations. What is important to mention is that the number of hospital beds currently meets the demand. New hospital inventory has also been provided in some of the hospital rooms. Overall, considering the donated equipment, the facility's equipment is rated at a moderate safety level.
The medical equipment, life support and resuscitation equipment cover more than 72 hours, which is quite sufficient as a stock, taking into account the fact that in the event of an earthquake, emergency supplies will be interrupted. It is in average condition (medium safety level), with measures taken for its bio-protection that are consistently respected.
The provision of supplies of materials and products in hospital conditions is more than necessary. In terms of medical supplies in the hospital, they are provided for a period of 15 days and are quickly available for use and application.

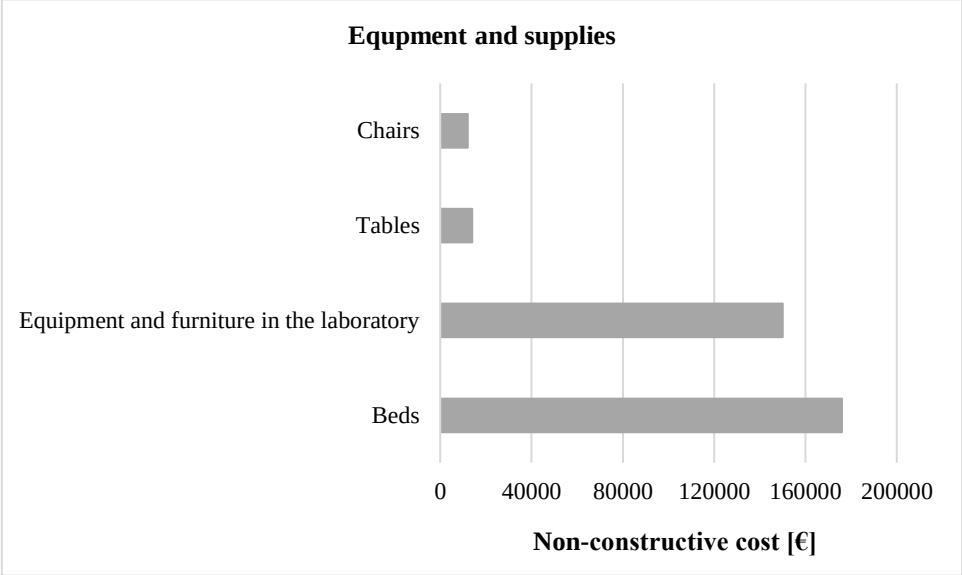

Figure 6. Cost Analysis of Non-Structural cost of Equipment and supplies

The results obtained (**Figure 6**) show that the highest non-structural replacement costs for equipment and supplies are expected for hospital beds in the "Main Building" with a total cost of around 176,000€.

3. Conclusions

This study evaluated the Non-structural Safety Index of the PHI "General Hospital" Strumica, with a specific focus on its Main Building. The findings indicate that the hospital demonstrates a medium to high level of safety for the majority of its non-structural elements.
For the purpose of this research, the Official Assessment Form for Non-Structural Safety Level of Non-Structural Elements, derived from the Official Hospital Safety Index (C3O, 2015), was employed as it represents the most accessible, standardized, and systematic tool for assessing the safety of non-structural elements in healthcare facilities. The use of such a standardized form not only enables the evaluation of individual hospitals, as in this case, but also facilitates national and international comparisons of hospital safety.
Ensuring high standards of both structural and non-structural safety in healthcare facilities should be a national priority—particularly for developing countries like ours. The results of this study can serve as a foundation for medium- and long-term disaster risk reduction planning, with the ultimate goal of decreasing urban vulnerability.

Furthermore, studies like this—offering detailed cost estimates for the renovation, reconstruction, or replacement of non-structural components—can support hospital administrators in making informed decisions about resource allocation, guided by prior disaster risk assessments.

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