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Decision on Strengthening Public Buildings Affected by Earthquakes: A Study on the Effective and Efficient use of Resources

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ABSTRACT

Current technological advancements are reshaping the public administrative service structure in response to needs and demands, making the modernization (repair/reconstruction) of existing public service departments particularly necessary. The impact of these developments on public building construction necessitates a more comprehensive, sustainable new model of public service buildings that can meet the present and future projections. Given the limited scope of the public sector internationally, the digital complexity of existing public administrative buildings, and the need for thorough planning and analysis to determine whether these components deliver the desired performance (fulfilling the requirements of the service provided), this research examines existing literature and official sources related to the planning and demolition of public administrative buildings. The design, service life, maintenance and repair, strengthening, and demolition phases are addressed using an expert evaluation method, considering strengths and weaknesses, potential damage, and mitigating possible explosions. It has been assessed that public service administrative buildings should be evaluated comprehensively using multi-criteria decision support analyses, particularly in the planning phase, to ensure the desired performance and to allow for the implementation of necessary changes to the required length. This will ensure the most accurate planning and utilization of public services.

Keywords: Earthquake; Reinforced Concrete Buildings; Public Buildings; Reinforcement; Repair; Demolition; Reconstruction; Assessment; Use of Public Resources; Decision Making.

1. Introduction

Project and investment is the effort to concentrate thought around a subject, to consider all the details in order to solve the problem, and to systematically determine and present the methods to be applied. Project development is essential for the efficient use of resources in complex, long-term projects with many stages and requiring large expenditures. It is the behavior of examining and evaluating, qualitatively and quantitatively, all the technical, economic, and social conditions and environments in which an investment transaction will be located and affected, and the variables related to them, from the moment it is implemented until the end of its economic life [1],[2].

The production process in the construction industry differs from other sectors in that it has a unique, non-repeatable, and complex structure. This structure is primarily involved in a complex relationship with people, the environment, materials, environmental processes, and many other factors.

While buildings like residences are sufficient to meet needs over time, public administrative service buildings become inadequate to meet those needs. Many older public buildings lack original plans, or if they do, have undergone numerous changes over the years due to necessary revisions, yet these alterations often fail to bring them to the desired level. Efforts are made to create suitable spaces for providing the required public services by constructing additional service buildings next to the administrative building, combining or separating various rooms, making them accessible to disabled individuals, strengthening them, expanding the heating and cooling system, etc. However, expenditures for these works must not exceed the building's operating costs; otherwise, it results in the ineffective, uneconomical, and inefficient use of public resources.

Law No. 5018 restructured the public financial management system, the preparation and implementation of public budgets, the accounting and reporting of all financial transactions, and financial control, in line with the policies and objectives included in development plans and programs, to ensure the effective, economical, and efficient acquisition and use of public resources, accountability, and financial transparency [3],[4].

1.1. Purpose and Scope

Recently, following earthquakes in various parts of our country, we have faced many irreplaceable losses of life and significant material damage. These earthquakes have once again demonstrated that there are two (2) options for a large portion of the existing building stock: "Reinforcement" or "Demolition."

This study argues that public buildings at risk of earthquakes should be reinforced; it aims to determine the effective parameters for making decisions regarding demolition and reconstruction. Reinforcement decisions for the buildings addressed in this study are generally based on economic indicators.

While structures such as residential buildings partially meet their needs (the service expected from them) over time, public service buildings fail to demonstrate the structural and functional performance expected of them over time and incur various maintenance/repair costs throughout their service life. These costs have been analyzed based on actual tender data, and the results are presented.

Such studies, which provide informative and guiding support to decision-makers, are also important in terms of the economic, social, and labor efficiency of public resources.

2. General Concepts

2.1. Public Service Buildings

Real estate is also an element of service delivery by public administrations. Article 45 of the Public Financial Management and Control Law No. 5018 authorizes public administrations within the scope of General Administration to acquire movable and immovable properties in the necessary quantity and quality, domestically or abroad, by paying the price in cash or instalments, or through financial leasing, when public services necessitate it. Within the framework of the Regulation on the Registration of Immovable Properties Belonging to Public Administrations, published in the Official Gazette dated 02/10/2006 and numbered 26307, public buildings are classified at the first level as follows: [5],[6].

- Administrative buildings (Service buildings)
- Buildings and facilities for education and training purposes
- Buildings and facilities for healthcare services
- Buildings and facilities for social and cultural purposes
- Buildings and facilities for sports purposes
- Buildings and facilities for tourism and recreation purposes
- Residences (public residences)

- Prisons, correctional facilities, and detention centres
- Commercial buildings and facilities
- Storage buildings
- Historical and well-maintained structures
- Industrial and production buildings and facilities
- Agricultural buildings and facilities
- Military buildings and facilities

2.2. Public Service Building Planning

Public buildings will be designed to accommodate different usage models and functions to meet changing needs throughout the building's lifespan. Accordingly, it is essential to:

- Provide solutions that allow for easy changes in space size and function when needed;
- Consider changing spatial scenarios during the mechanical and electrical installation design phase;
- Design transparent and opaque surfaces on building facades to accommodate changing interior space scenarios.

In the design of public buildings of this type, the organization can be protected in terms of functionality and usability with the quality of "scalability". The characteristics of the public institution that will serve in the building can be increased [7].

2.3. Maintenance – Repair

Maintenance and repair work on existing public buildings is limited to "regular maintenance and repair work directly related to operation, excluding maintenance and repair work aimed at growth and not related to their economic lifespan and cost "[8]. Maintenance and repair of existing public buildings is carried out by expert technical personnel after on-site inspection following a maintenance and repair request made by the public institution/organization using the building. Maintenance and other needs are identified. In line with this, the principles for preparing technical reports and making payments are established, and the sequential processes are continued within the framework of the legislation [9].

2.4. Strengthening – Demolition or Reconstruction

In our country, 96% of which is located in an earthquake zone, it is obvious that natural disasters are inevitable. Therefore, we need to learn to live with natural disasters and design earthquake-resistant structures. Because the main element threatening life is not natural disasters, but the fact that structures are not built-in accordance with the rules of science and art. It is understood from the natural disasters we have experienced and from the building inventory studies that have been partially carried out that a large part of the existing building stock in our country does not have the desired level of earthquake resistance, and that the majority of buildings are illegal, unlicensed and without engineering services [10]. The demolition and reconstruction of existing buildings has gained momentum with the increasing urban transformation activities in recent years and has become one of the most

important activities in the construction sector. However, the decision to demolish and rebuild a building should be made after sufficient research on this subject and evaluation of alternatives. In order to make this decision, a lot of information is needed, especially regarding the cost of demolition and reconstruction.

In practice, in order to make this decision, the Republic of Turkey... The building cost ratio recommended by the Ministry of Environment and Urbanization, which is calculated by dividing the building strengthening cost by the total of the building demolition and reconstruction costs, is taken into consideration. However, there is no official information on which factors influence this recommended 40% ratio and why it is 40% [11],[12].

2.5. Existing Building Assessment

The economic and functional value of buildings can decrease over time due to many reasons such as physical and environmental impacts, human-induced interventions, and legal requirements. Consequently, physically obsolete, low-performing buildings are either demolished or renovated by replacing their technical infrastructure or all structural elements. However, to achieve sustainable solutions that support these two possible outcomes, it is essential to first clearly define the needs [13].

The life cycle cost of buildings is defined in the ISO 15686-5 standard by the International Organization for Standardization (ISO) as the total cost obtained by subtracting the salvage value of the remaining asset after evacuation from the costs of planning, design, construction, operation, maintenance and repair, and evacuation of the building or its components. This concept is defined in the ASTM E917-13 standard published by the American Society for Testing and Materials International (ASTM) as the total cost of design, purchase, lease, construction, assembly, operation, maintenance, renovation and disposal for a specified period of time to choose among investment alternatives that will perform the same task [14].

The building has sufficient structural safety and does not require repair and/or maintenance. Although this may seem like an easy decision at first glance, the need for a thorough and reliable assessment by a team of experts from the existing internal units, clear elimination of all doubts regarding the building's condition, etc., makes it difficult to add this decision. A decision to restrict use without any intervention is not a desirable solution for building owners or users, as it does not comply with many regulations. From a societal perspective, this often does not mean the building is structurally safe against earthquakes, and the building will subsequently be labelled a "dilapidated building." The last two options involve a significant economic assessment for repair/strengthening or demolition. If the building in question is privately owned, the decision is made by the property owners. In case of any disputes, the decision can be made by the competent court, taking into account the Civil Code, the Condominium Law, and Law No. 6306 on the Transformation of Areas Under Disaster Risk [15].

However, the content of the decision in question can be found with many parameters such as how it will be put together for public buildings, the situation, condition and variable. As stated above, for public buildings where a decision should be made for repair/strengthening or demolition, the cost calculated within the scope of the renewed project is usually evaluated according to whether the value resulting from the ratio of the cost of rebuilding the building is lower or higher than 0.40 (40%). In addition to the 40% value mentioned, an economic evaluation of the

decision is needed with the use as a general set, and a more comprehensive evaluation is needed with the structure of benefit-cost analysis on the situation [15].

3. Materials and Methods

A significant portion of Turkey's land consists of earthquake-prone areas and fault lines, and unfortunately, densely populated cities and major industrial facilities are also located in these regions.

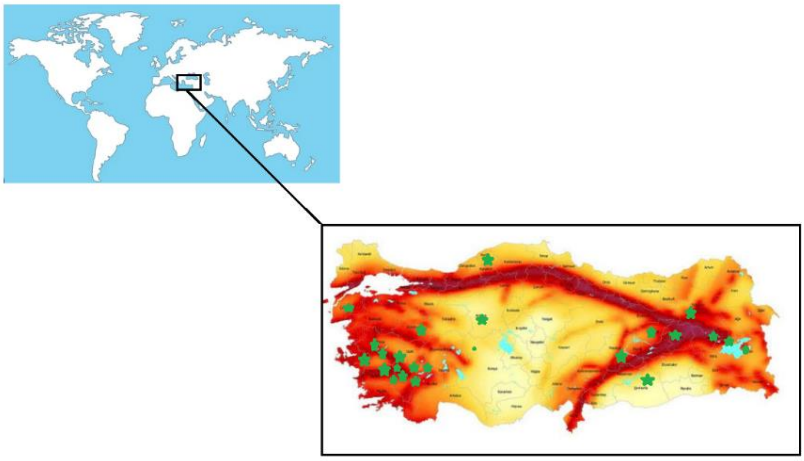

Figure 1. Location of the Region Covered by the Study

In this study, reinforcement and repair projects and estimated costs obtained from the Provincial Environment and Urbanization Directorates and the Public Procurement Authority (KİK) databases will be used for public buildings (schools and administrative service buildings) that were subject to reinforcement and repair tenders and completed between 2011 and 2015 (5 years).

New construction cost values were calculated using unit prices obtained from the approximate unit construction cost table published in the Official Gazette of the relevant year and enacted by the Council of Ministers Decision. Primary schools were taken as the basis for schools, while administrative buildings (district-type public buildings, tax offices) were taken as the basis for public administrative service buildings.

A total of 24 reinforcement and repair projects carried out and completed in accordance with Article 19 (Open Tender) of the Public Procurement Law No. 4731 were selected. Twelve of the projects used in the study are elementary schools (high schools and elementary schools), and 12 are public administrative service buildings. Particular care has been taken to select sample buildings from provinces located in earthquake zones.

Table 1. Data on Educational Institution Buildings

Public Education Institution Buildings (Example-1)					
Sequence No.	City	Year of Construction	Total Enclosed (m^2)	Approximate Cost (TL)	Reinforcement + Maintenance and Repair Cost/Reconstruction Cost Ratio (%)
Example.1.1	İzmir	2011	321.93	198,708.17	109.2
Example.1.2	Manisa	2013	2,823.17	575,250.90	34.7

Example.1.3	Manisa	2013	962.57	182,294.00	39.8
Example.1.4	Denizli	2015	2,824.00	1,050,000.00	41.1
Example.1.5	Denizli	2011	854.00	167,648.95	50.1
Example.1.6	Denizli	2011	2,400.00	540,364.77	34.8
Example.1.7	Denizli	2012	724.00	166,666.70	32.4
Example.1.8	Denizli	2014	3,834.00	536,008.91	31.6
Example.1.9	Denizli	2014	2,819.00	1,050,000.00	38.0
Example.1.10	Van	2013	6,782.00	1,252,012.00	21.5
Example.1.11	Afyonkarahisar	2013	976.55	216,915.36	57.3
Example.1.12	Bingöl	2012	1,709.55	479,232.30	53.1

Table 2. Data on Public Administrative Service Buildings

Public Administrative Service Buildings (Example-2)					
Sequence No.	City	Year of Construction	Total Enclosed (m^2)	Approximate Cost (TL)	Reinforcement + Maintenance and Repair Cost/Reconstruction Cost Ratio (%)
Example.2.1	Manisa	2013	757.00	364,687.00	16.3
Example.2.2	Malatya	2012	1,000.00	91,194.00	45.6
Example.2.3	Bartın	2013	780.00	344,000.00	60.1
Example.2.4	Şanlıurfa	2013	4,011.00	527,893.00	144.8
Example.2.5	Isparta	2013	3,912.30	2,103,270.83	82.4
Example.2.6	Muş	2012	1,178.00	300,581.21	75.4
Example.2.7	Denizli	2012	1,648.00	555,535.13	22.5
Example.2.8	Erzurum	2015	264.62	73,295.00	91.7
Example.2.9	Çanakkale	2015	1,850.00	283,791.00	63.9
Example.2.10	Ankara	2014	658.22	273,537.96	96.4
Example.2.11	Tunceli	2014	1,177.86	737,908.61	39.6
Example.2.12	Van	2012	656.21	532,930.51	21.9

4. Results

The buildings of the Basic Education Institutions examined are cataloged as Example.1.1, Example.1.2, ... and the Public Administrative Service Buildings are cataloged as Example.2.1, Example.2.2, ... respectively. Special importance was given to selecting examples from cities in earthquake-prone regions.

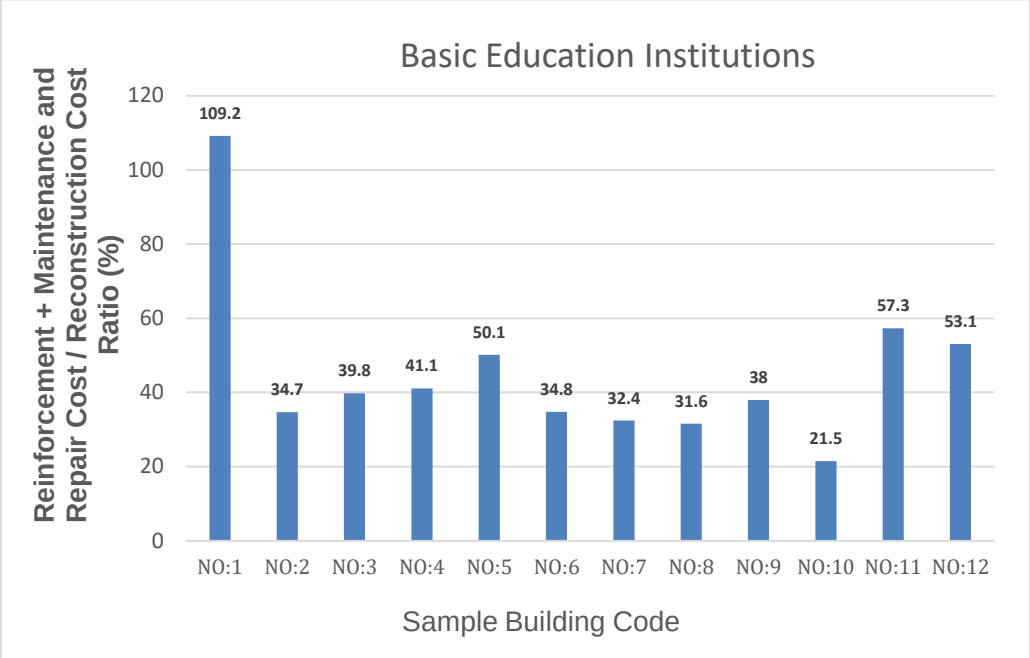

Figure 2. Graphs of Educational Institutions

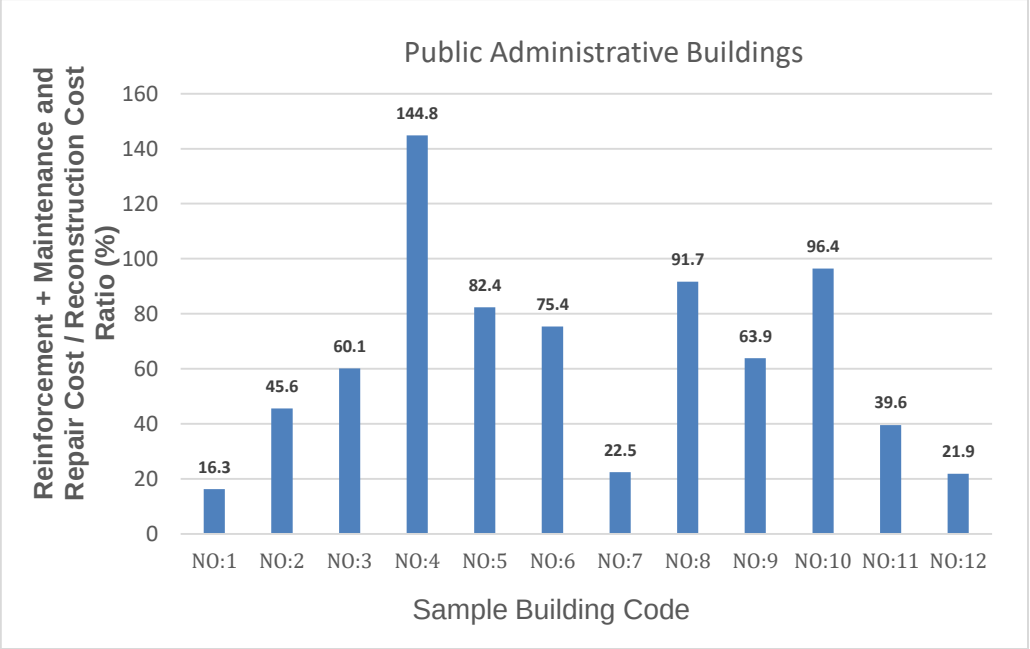

Figure 3. Graphics of Public Administrative Buildings

In the context of Public Education Buildings, an assessment of the Strengthening + Maintenance and Repair Cost / Reconstruction Cost Ratio (%) revealed that 5 out of 12 sampled buildings exceeded the suggested reference value of 40%. Regarding public administrative buildings, an evaluation of the Strengthening + Maintenance and Repair Cost / Reconstruction Cost Ratio (%) indicated that 9 out of 12 sampled buildings surpassed the recommended reference value of 40%.

When examining the ratio of Repair and Reinforcement Cost to Reconstruction Cost in public service buildings, we observed that repair and reinforcement tenders exceeding the critical threshold of 40% were awarded at significantly higher values compared to tenders for primary school institutions.

It has been observed that even when the 40% allocation for maintenance and repair costs/reconstruction costs recommended by the Ministry of Environment and Urbanization is not used, and even when the allocation is 100% or higher, strengthening and repair applications are carried out.

Especially in public service buildings (PBUH), it is observed that decisions regarding strengthening and repair are made without a comprehensive review of the buildings, and that economic evaluation criteria alone are insufficient for making decisions about repair, strengthening, or demolition in such structures. This is supported by practical applications.

The following criteria should be evaluated together:

a) Historical and architectural value the building contributes to the region,

b) Function, importance, and priorities of the building's intended use,

c) Building's capacity to fulfil the planned service (whether it meets the requirements of the service),

d) Whether the building meets the possibilities for strengthening and repair, demolition, or reconstruction,

e) Possibilities available in terms of authority, permits, and legal framework,

f) Age and service life of the building, etc.

When comparing public buildings (Primary Education Institutions and Public Service Buildings) for which strengthening and repair tenders have been conducted;

5. Conclusion

Most older buildings providing public services (schools, dormitories, hospitals, administrative service buildings, etc.) face two options when subjected to seismic performance analysis: "reinforcement" or "demolition". It is nearly impossible to carry out reinforcement or demolition/reconstruction work without disrupting the services provided in the building. Therefore, when public administrators make decisions regarding demolition or reinforcement, it is essential to ensure the effective and efficient use of public resources by employing the correct analysis parameters.

Based on the data obtained from the study, for public buildings that require reinforcement:

- The 40% rule used as a reference for the strengthening cost/reconstruction cost ratio is not a sufficient criterion on its own.
- A multi-criteria analysis is necessary, primarily considering the building's structural, functional, and user expectations.
- Building performance and service continuity should be evaluated based on future years of use, requiring policy updates.
- Investment projects included in the planning should be geared towards supporting the developing potential of the region, creating employment in the region, and increasing prosperity, within the framework of developed development and action plans.

The limited budget allocated to public building investments (administrative service buildings, schools, hospitals, dormitories, etc.) and existing structures, and the fact that this budget exceeds the budget allocated to public construction/repair projects within the scope of investment proposals, means that the resulting choice/decision-making process should be analysed not only economically but in all its aspects.

For a public administrative service to be carried out, the entire Building Life Cycle (BLC) – from the planning phase to the execution and termination (demolition) phase – must be evaluated as a whole. Data selection processes should be carried out on the obtained data.

In future studies, when developing decision-making models for existing buildings located in areas with a high risk of earthquakes, it is essential to implement an integrated decision model that incorporates multi-criteria decision analysis methods. This model should encompass factors such as cost, continuity of public services, structural performance, user expectations, and sustainability indicators.

Declarations

Source of Funding

This study did not receive any grant from funding agencies in the public or not-for-profit sectors.

Conflict of Interest

The authors declare that they have no conflict of interest.

Consent for Publication

The authors declare that they consented to the publication of this study.

Authors' contributions

Both the authors took part in literature review, analysis, and manuscript writing equally.

Ethical Approval

Not applicable for this study.

Informed Consent

Not applicable for this study.

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