

Factors Affecting Quality in Construction

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Achieving a high level of quality in a residential building, characterized by the highest level of performance features, is crucial for the client and all participants in the investment process. The identification of negative factors that occur in the investment process, and the assessment of their impact on the quality of the facility, provide important knowledge that gives the basis for controlling the course of the process.

Keywords: quality ; construction defects ; quality management ; housing construction ; influence factors ; civil engineering

1. Introduction

The investment process in the construction industry is multi-stage and complicated. At its individual stages, disruptions may occur, which in turn translates into there being a high investment risk and a low quality of completed building objects. Achieving a high level of quality in a residential building, characterized by the highest level of performance features, is crucial for the client and all participants in the investment process. Therefore, it is reasonable to find the answer to the question of which factors generated during the individual stages of the construction process affect the final quality of the building, and also what impact these factors have on the formation of defects in residential housing. Researchers, dealing with the issue of housing quality in various countries of the world, have identified a number of recurring defects in residential building elements ^{[1][2][3]}. The subject of analysis has also been the factors influencing the formation of defects identified at various stages of the investment process ^{[4][5]}.

Quality means a set of product and service features that subjectively create the value of a product, which in turn affects the fulfilment of the customer's expectations. It can be unequivocally stated that quality is currently one of the main factors necessary for an enterprise to achieve market success ^[6]. It is the quality of workmanship that determines whether a construction project will be positively perceived by customers ^[7]. Without taking into account quality or a quality management system, a company cannot survive in a volatile market in the long term.

2. Defects Found in Residential Buildings

The measure of quality is the number and type of defects that can be found during the technical acceptance of building structures. Physical defects involve the inconsistency of the sold item with the contract (Announcement of the Marshal of the Sejm of the Republic of Poland from 9 June 2022 on the publication of the consolidated text of the Act—Civil Code ^[8]). The sold item is inconsistent with the contract if it does not have the properties that it should have regarding the purpose specified in the contract, if it does not have these properties as a result of circumstances or intended use, if it does not have the properties that the seller assured the buyer about, if it is not suitable for the purpose that the buyer informed the seller about at the conclusion of the contract and the seller did not object to such a purpose, or if it was delivered to the buyer incomplete.

Defects are a common phenomenon in the construction industry. They are the result of design errors, the use of poor quality building materials and poor workmanship. There are many publications regarding the quality and the frequency of defects in residential buildings ^{[1][2][3][9]}. For example, Ojo and Ijatuyi ^[10] conducted a study of defects using the Sunshine Gardens estate in Akure, Nigeria. The authors found defects in all the elements of both the building's construction and finishing. The most common defects with regard to the roof structure and its covering included the use of low-quality materials, improper wood processing, poor workmanship, and the inaccurate supervision of construction workers. Low-quality materials were used to build the walls, and the window and door lintels were too short. The floors were made of low-quality materials.

In turn, based on research conducted in Spain ^[11], 3647 defects were localized and classified in a set of 68 completed residential buildings. The defects were divided into three groups, namely:

- The type of defect (lack of functionality, detachment of an element, lack of levelness, incorrect assembly, curved surfaces, dirt on elements, incorrect external appearance, incorrect dimensions, and problems with water);
- The element of the building in which the defect was found (ceiling, concrete walls, doors, external joinery, elevation, floor, wooden elements, plasters and internal walls, various elements, electrical installations, sanitary installations, pillars, roof, paving slabs, stairs, and windows);
- The location of the defect in the building (common areas, external facades, floors, garages, kitchens, bedrooms, restrooms, rooms, terrace, and washrooms).

Plebankiewicz and Malara ^[12] classified defects in residential buildings into three groups:

- Defects of great importance—causing a defect that prevents the proper functioning of the premises, which may pose a threat to the health or life of people. Removing very important faults usually requires removing the causes and their effects. Examples of very important defects include flooding of the property, cracking of a structural element, short circuiting the electrical installation, causing a fire, or having a leak in the roof covering;
- Significant defects—causing limitations in the proper functioning of the facility. This definition defines a number of defects that limit the possibility of unlimited use, but do not force the cessation of use, as they do not pose a direct threat to the health and life of users. Examples include intercom failure, deteriorating tiles on the balcony, leaking window and balcony joinery, or slow-acting locks on the main doors;
- Defects of minor importance—these are minor defects that do not impede the functioning of the premises. These are defects of a visual or cosmetic nature. Removing these defects does not require the use of any advanced technology, and the time to remove them may vary. They can be illustrated with the following examples: scratches on walls, paint chips, spontaneous scratches on glass, or silicone detachment on balcony tiles.

Forcada et al. ^[13] pointed out the great importance of the inspection of construction processes by future owners. Although inspections take place during construction or at the time of handover, clients usually do not participate in them. This situation creates a gap between the quality perceived by both contractors and customers. The article presents an analysis of 52,552 acceptance defects in 2179 apartments in Spain, identifying their nature, construction element, and the industry in which these defects are found. These results were compared with previous studies that analyzed defects detected at the construction stage and those that remained after the building was handed over to the client. Studies have shown that construction defects are removed during construction thanks to existing quality standards. However, aesthetic and functional defects remain at the time of delivery. The authors conclude that many functional defects result from the lack of end-user involvement in the early stages of the project.

Similar studies were conducted by Shirkavand et al. ^[14]. The article presents research on the most common building defects at the time of handing over the buildings for acceptance, the causes of defects, the consequences for the main contractor, subcontractors, users and customers, and the possibilities of improvements (repairs). The results show that the most common defects recorded at the time of handing over the building are defects related to surface damage. Repairing them is neither difficult nor expensive. Another area where the most common negative deviations occur are defects related to technical installations. Unfortunately, this is often a serious problem because it prevents the entire building from fully functioning. The main cause of defects is incompleteness and poor design, and the main consequences of defects are economic losses and erosion of trust between the various stakeholders in the construction industry.

Rotimi et al. ^[15], using 216 residential buildings commissioned in 2008–2011 in New Zealand, determined the level of detection of defects by independent building inspectors. The most common defects included uneven painting, nail marks, poor quality finishing of rooms and floors, improperly fitted door and window handles, cracks in buildings, and the incorrect installation of toilets.

Ismail et al. ^[16], point out that construction defects are a common problem in housing provisions in Malaysia. Theoretically, new homes should be free from defects. To verify the quality of the apartments being built, buildings should be inspected from the early stages of construction until the handover stage. Defects are identified and classified by defect type, and the overall results indicate that most common construction defects in new homes are cosmetic. These defects are mainly due to poor workmanship. To mitigate this problem, developers must ensure that contractors are qualified, and that a thorough building inspection has been performed before handover of the home.

Gurmu and Paton-Cole ^[1] studied defects in residential buildings in the Australian state of Victoria. Most defects in these buildings were often hidden and appeared during the building's use. Therefore, repairing these defects becomes difficult and expensive because access to the source of the defective components in the completed building may be difficult.

The analysis of selected articles indicates that defects in housing construction are common. They are located in various elements of buildings ^{[11][14]}, in regards to the structure and finish, and may affect the safety of use of apartments to varying degrees ^[12]. They are generated at various stages of the investment process, both during the design, construction, and operation of the facility ^{[13][17]}. Defects in the building's structural elements should be identified in the earlier stages of construction because they are covered during the finishing works ^{[1][13]}. By far the largest number of defects are cosmetic. Removing defects in residential buildings involves additional financial outlays. In order to avoid the above problems, research should be conducted to identify the factors that influence the generation of faults in the investment process and to determine their impact on the quality of housing construction.

Table 1 contains a synthesis of defects occurring in construction identified based on the literature.

Table 1. Synthesis of research results on the defects in residential buildings based on a literature review.

Authors	Statements
Ojo and Ijatuyi ^[10]	The most common defects in roof construction and roofing were the use of low-quality materials, improper woodworking, poor workmanship, and inaccurate supervision of construction workers. Low-quality materials were used to build the walls, and the window and door lintels were too short. The floors were made of low-quality materials.
Forcada et al. ^[11]	Defects were divided into three groups: the type of defect (ack of functionality, detachment of an element, lack of levelness, incorrect assembly, curved surfaces, dirt on elements, incorrect external appearance, incorrect dimensions, and problems with water), the elements of the building (ceiling, concrete walls, doors, external joinery, elevation, floor, wooden elements, plasters and internal walls, various elements, electrical installations, sanitary installations, pillars, roof, paving slabs, stairs, and windows), and the location of the building (common areas, external facades, floors, garages, kitchens, bedrooms, restrooms, rooms, terraces, and washrooms).
Forcada et al. ^[13]	The research shows that construction defects are removed during construction thanks to existing quality standards. However, aesthetic and functional defects remain at the time of delivery. The authors conclude that many functional defects result from the lack of end-user involvement in the early stages of the project
Plebankiewicz and Malara ^[12]	Defects were classified into three groups: Defects of great importance. Examples: flooding of the property, cracking of a structural element, short circuit of the electrical installation, causing a fire or leaking roof covering. Significant defects. Examples: intercom failure, deteriorating tiles on the balcony, leaking window and balcony joinery, or slow-acting locks on the main doors. Defects of minor importance. Examples: scratches on walls, paint chips, spontaneous scratches on glass or silicone detachment on balcony tiles.
Shirkavand et al. ^[14]	The most common defects recorded at the time of handing over the building are defects related to surface damage. Repairing them is neither difficult nor expensive, as opposed to defects related to technical installations.
Rotimi et al. ^[15]	The most common defects included uneven painting, nail marks, poor quality finishing of rooms and floors, improperly fitted door and window handles, cracks in buildings, and the incorrect installation of toilets.
Ismail et al. ^[16]	The most common construction defects in new homes are cosmetic.
Gurmu and Paton-Cole ^[1]	Most defects in these buildings were often hidden and appeared during the building's use. Therefore, repairing these defects becomes difficult and expensive because access to the source of the defective components in the completed building may be difficult.

3. Factors Affecting Quality

The identification of factors that influence the quality of housing construction should be the basis for the activities of every construction company. This is confirmed by Crosby's vision of quality ^[18] in which the author states that quality applies to all the areas of a company's activity, and can be measured with the use of costs.

The final quality of a building is the sum of all the factors related to the two basic creative aspects of the building, namely ^[19]:

- Material aspects—resulting from the proper selection and use of building materials during the implementation of investments;
- Personal aspects—all the aspects related to the work of qualified people responsible for managing the design and implementation of works, supervision, and production by persons with appropriate qualifications, preparation, experience, and technical knowledge.

The research presented by Ahzahar et al. in ^[20], which was conducted in Penang (Malaysia) among participants of the construction process, indicated the following material factors that are important for the quality of residential buildings: the improper use of building materials, and damage to materials during construction. Inaccurate material specifications or the delivery of low-quality materials to the construction site can also be a source of defects in residential buildings ^{[21][22][23]}.

In turn, with regards to personal factors, the most commonly mentioned are the insufficient skills of employees and mistakes made by them, poor experience and knowledge of the manager, and a shortage of qualified employees ^{[22][24][25]}.

Josephson and Hammarlund ^[26] analyzed 2879 faults collected in 7 construction projects and identified 5 different types of fault causes, namely knowledge, information, motivation, stress, and risk. Jha and Iyer ^[27], by analyzing the responses of specialists in about 50 large- and medium-sized organizations in the Indian construction industry contained in research questionnaires, identified the reasons that negatively affect the quality of construction: difficult climatic conditions in the construction site, negative attitude of project participants, ignorance and lack of knowledge of the project manager, etc.

Ojo and Ijatuyi ^[10] indicated that the main factors contributing to defective construction are the use of substandard building materials, poor workmanship, inadequate supervision, and design deficiencies. As countermeasures, they pointed to strict supervision, proper construction management and quality control, thorough training and education of craftsmen, and the use of high-quality materials. The paper's authors also recommended the use of appropriate construction management and quality control measures to reduce the occurrence of defective construction and promote a pleasant living environment.

In research presented by Atkinson ^[25] conducted among people holding managerial positions during the implementation of investments, it was emphasized that errors in managerial decision making have a more significant impact on the product than omissions made by employees. The following factors, which depend on the managerial staff and which influence quality, were indicated: the manager's experience and knowledge, manager qualifications, the level of informal communication, the quality of formal communication, organizational culture, poor planning and programming, a lack of strategic planning, the poor quality of project management, delays in decision-making, a lack of control in the investment process, cost and time pressure, and also poor communication between the designer and the contractors. The important role of training and education in the field of management in the context of identifying the correct technical solutions was also indicated. In addition, the phenomenon of corruption can also be seen to be of great importance for the quality of buildings. This is particularly visible in developing countries ^[21].

The design phase and the proper preparation of design documentation is of key importance for the quality of buildings under construction. Tayeh et al. ^[28] identify the main factors that affect the occurrence of defects at the design stage of residential buildings in the Gaza Strip. For the purposes of the analysis, a survey was carried out which identified three main design errors: ignored or incorrectly performed soil tests, a lack of qualified supervision of drawings, and inconsistency between architectural and construction drawings. In addition, the authors of studies ^{[20][22][24]} point to the quality of the design, namely poorly made project documentation ^[20], the ambiguity of design details, and the introduction of changes to the structure of the facility ^{[22][24]}.

During the construction and operation phase, attention was paid to the type and location of the building, climatic conditions, occupational safety challenges during project implementation, the lack of inspection and inadequate supervision on the construction site, the lack of required maintenance, as well as changes with regards to using the facility ^{[17][20][22]}.

Based on surveys conducted among employees of design offices, consultants, contractors and building owners who are responsible for the design, execution, and maintenance of residential buildings, it was shown that the assessment of the impact of factors on quality depends on the evaluating group ^[23]. Contractors considered architectural design flaws to be the most significant, consultants considered defects resulting from the technical specification as the number one factor, and clients considered defects in the architectural design as the most important.

The authors of many studies emphasize the importance of controlling the construction process to obtain a high-quality product [4][21][22][24][25]. Fernández et al. [4] analyzed various quality control factors in housing projects in Spain. Based on their research, they proposed changes regarding control, which involved paying attention not only to the management process but also to the quality and control of the supply of materials. Zalejska et al. proved that the size of the development company and the location of the building also have a significant impact on construction defects [29].

The occurrence of defects in residential buildings is associated with the need to remove them, which in turn generates significant costs. Based on research conducted by Mills et al. [30] in Australia between 1982–1997, it was found that the cost of repairing defects is about 4% of the contract value. In turn, Josephson [26] found that the cost of repairing defects corresponds to 4.4% of the construction costs of buildings, and the time to repair them is 7% of the total working time.

Defects result in the budget for a construction investment being exceeded. Therefore, an important element of research in this area is the search for a model approach for managing defects. This approach was proposed by Park et al. [31] in the form of a building defect management system with the use of augmented reality (AR) and Building Information Modeling (BIM). Chatterjee et al. proposed a model for predicting defects in multi-story reinforced concrete buildings using neural networks (NN-PSO classifier) [32], while Aljassmi and Han proposed a model for analyzing the causes of defects and faults using trees and measures of risk [5].

Defects in residential buildings can occur in all of their elements. Verification of the nature of the detected defects and the identification of factors that influence their creation may lead to valuable conclusions regarding company management, which in turn will affect the achievement of high-quality residential buildings.

Based on the conducted study of the literature, it was found that the main factors that influence the formation of construction defects are material factors and personal factors. Material factors include the improper use of building materials, the delivery of low-quality materials to the construction site, damage to materials during construction, incorrect and poorly executed technical specifications, and non-compliance with the specifications of the performed works. However, personal factors also have a decisive impact on the phenomenon of defects and faults in residential buildings. Studies have shown that the main factors that affect quality include human factors at the managerial level. Based on the literature review regarding the identification of defects and the factors that affect their generation, no studies were found that would indicate the strength of the impact of individual factors on the formation of defects. This is an area of research that is a blank spot in the field of research regarding quality in housing construction. This issue is the subject of the research presented in this article.

Table 2 lists the factors influencing the generation of defects identified based on the literature.

Table 2. Summary of research results on factors influencing quality in construction.

No. of Factor	Literature Item	Type of Factor	Description
1	[10][14][20][22][24][28]	Errors in the design documentation	design errors, faulty structural and architectural design, ambiguity of design details, omission to take into account the conditions of use (maintenance) at the design stage, defects in construction drawings
2	[4]	No legal basis for the design	lack of design standards, incompatibility of the project with existing technology
3	[22][24]	Making changes to the structure	changes in structure during construction and use
4	[10][16][22][23][25]	Qualifications and skills of workers	unskilled contractors, insufficient skills of workers, contractor errors
5	[10][22][23][25][27]	Qualifications and skills of the management staff	qualifications, experience and knowledge of the manager, skills related to construction
6	[10][24][25][29]	Quality management	lack of quality management during construction, lack of control during construction, poor supervision on site
7	[27][33]	Engagement	involvement of the supervisory team, involvement of other employees
8	[25][29][30]	Construction management skills	poor planning and scheduling, delays in decision making, planning/programming
9	[24][25][30]	Team communication	lack of communication, level and quality of formal and informal communication, organizational culture, lack of communication between the designer and contractors

No. of Factor	Literature Item	Type of Factor	Description
10	[10][20]	Lack of work teams	lack or deficiency of resources
11	[10][20][21][22][23]	Delivery of materials not in accordance with specifications	non-compliance with specifications, incorrect specifications, defects resulting from material specifications, use of unqualified trade subcontractors
12	[10][20][21][22][23]	Poor materials management	poor material management, improper use of building materials, damage to materials during construction
13	[27]	Climatic influences	difficult climatic conditions, bad weather conditions
14	[14][25]	Financial difficulties, time	client's financial uncertainty, cost pressure, time pressure
15	[13]	End customer engagement	participation of the end customer in technical acceptance

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