TECHNICAL TRANSACTIONS | **CZASOPISMO TECHNICZNE**
CIVIL ENGINEERING | BUDOWNICTWO

1-B/2014

JAKUB PIASNY, JERZY PASŁAWSKI*

METHODOLOGY TO IDENTIFY THE CAUSES OF THE CONSEQUENCES OF DEFECTS IN BUILDING CONSTRUCTION

METODOLOGIA IDENTYFIKACJI PRZYCZYN POWSTAWANIA NASTĘPSTW WAD W BUDOWNICTWIE KUBATUROWYM

A b s t r a c t

To rationally prevent defects, you must first have knowledge of the defects, their causes and the associated costs. A key objective of the research presented is to attempt to demonstrate the application of various methods used in production engineering, in the context of today's economy requirements and transfer knowledge gained from previously completed projects, with the aim of increasing the quality multifamily housing. A study of faults and subcontractors was carried out for the period 2006/2013. Eight construction projects with a total usable area of approximately 117,000.0 square meters and 1,524 apartments were studied. This is one of the first studies, for this period, carried out based on multifamily building projects in Poland.

Keywords: six sigma, defect, quality, chart, Pareto-Lorenz

S t r e s z c z e n i e

Aby wykonać racjonalną profilaktykę wad, trzeba mieć wiedzę na temat usterek, ich przyczyn i związanych z tym kosztów. Kluczowym celem badań prezentowanych jest podjęcie próby wykazania zastosowania różnych metod stosowanych w inżynierii produkcji w kontekście współczesnych wymagań gospodarki oraz przekazanie wiedzy zebranej z zrealizowanych projektów powodującej wzrost jakości w budownictwie wielorodzinnym. Badanie występujących usterek oraz podwykonawców przeprowadzono za okres 2006/2013. Przebadano osiem projektów budowlanych o łącznej powierzchni użytkowej ok 117.000,0 m^2 i 1524 mieszkań. Jest to jedno z pierwszych przeprowadzonych badań w tym okresie dla budynków wielorodzinnych w Polsce.

Słowa kluczowe: six sigma, usterki, jakość, wykres Pareto-Lorenza

* M.Sc. Jakub Piasny, Ph.D. D.Sc. Eng. Jerzy Pasławski, Institute of Structural Engineering, Faculty of Civil and Environmental Engineering, Poznań University of Technology.

1. Introduction

In recent years, construction in Poland has been undergoing a fairly significant crisis associated with the collapse of the economy, while striving to keep the construction market buoyant during a period of aggressive competition, which has contributed to significant price reductions. The fall in prices has led to construction works being signed well below cost. This has resulted in cost cutting during implementation by pressing subcontractors to replace materials with cheaper options in order to fit the budget. In such situations, the work is completed, but the course of construction conditions are constantly changing [1]. To succeed in the embodiment of an error-free facility, companies must constantly develop and improve in different areas and by using different technologies. The long-term strategy is to improve the quality and competitiveness of the qualitative results, which are measured in terms of impact on the level of waste, rework, repair time, warranty costs, customer complaints, productivity, profitability, market share, costs and competitive position [2]. One example of the application of such new possibilities is the use of laptop computers to collect data from the construction [3, 4]. Changes must be knowledge based, as incomplete knowledge causes an increase in the risk of faulty execution of works, not carried out in accordance with specifications [5]. Possession of the necessary skills and knowledge to interact effectively improve the process is therefore essential. This paper examines work carried out by a construction company working with foreign capital .The survey was conducted for buildings in use from 2006–2013 in cooperation with a nationwide construction company with decades of experience in the performance of buildings of varying complexity. The study mainly focuses on the causes and types of defects and their diagnosis.

2. Description of objects

For the examination of contracts adopted and eight multi-family housing built and supplied for use in the period of 2006 to 2013. The buildings consist of the following:

1. Multifamily building built between 2008–2010 with a usable area of approximately 17,000.00 square meters, the volume of 97,000.00 cubic meters, and the number of apartments of 275;
2. Multifamily building built between 2010–2012 with a usable area of approximately 20,000.00 square meters, the volume of 56,000.00 cubic meters, and the number of apartments of 178;
3. Multifamily building built between 2006–2009 with a usable area of approximately 17,000.00 square meters, the volume of 47,000.00 cubic meters, and the number of apartments of 200;
4. Multifamily building built between 2007–2010 with a usable area of approximately 19,000.00 square meters, the volume of 75,000.00 cubic meters, and the number of apartments of 220;
5. Multifamily building built between 2006–2009 with a usable area of approximately 17,000.00 square meters, the volume of 47,530.00 cubic meters, and the number of apartments of 220;
6. Multifamily building built between 2006–2008 with a usable area of approximately 15,000.00 square meters, the volume of 79,000.00 cubic meters, and the number of apartments of 238;

7. Multifamily building built between 2004–2006 with a usable area of approximately 9,500.00 square meters, the volume of 23,000.00 cubic meters, and the number of apartments of 160;
8. Multifamily building built between 2007–2009 with a usable area of approximately 2,500.00 square meters, the volume of 6,500.00 cubic meters, and the number of apartments of 33.

The model implementation process was based on a construction schedule consistent with Fig. 1 Executed contracts depend on whether it is a public or private building. To improve future quality it is necessary to be aware of a number of factors, among others, knowledge that is already available in the form of books, procedures, reports, etc., which can be archived for use if required. It should also be noted that the information and knowledge must be collected from all bodies and institutions involved in the project, such as residents, designers, contractors, consultants, etc. [6].

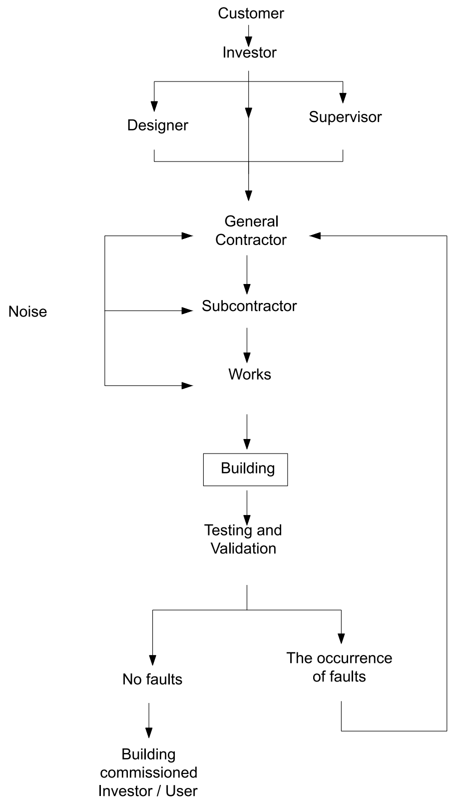

Fig. 1. Schematic project implementation

3. Research methodology

This paper aims to study the number and types of faults occurring with the help of modern methods of production engineering in use building in the Polish multifamily housing. Research methodology consists of a comprehensive review of literature, data sets and the analysis of statistical data, from the perspective of both the general contractor and the investor. Information on the occurrence of defects in construction came from a wide range of literature, including documents, books and magazines from around the world, as well as those specifically focused on the industry in Poland. Faults occurring during operation demonstrated 602 types of defects, which can occur during the execution of construction work. The work presents almost all of the risks that may occur in a building element during operation, considering buildings both in Poland and other countries. The 602 types of defects were divided into 3 groups, including 115 associated with the building element. After each contract, the company conducted a survey with the service provider was carried out using a contract assessor: meeting deadlines, quality of product/services, technical potential and the fulfillment of all conditions in the contract. Information on the assessment of subcontractors will look at the impact directly on the occurrence of faults.

3.1. The method of data analysis

The study includes the impact of defects on all contracts due to: the type of defect, the number of faults, repair costs and repair time. To carry out research using the following methods occurring in manufacturing engineering:

Table 1

Examples of applications of particular methods of quality management

DMAIC Stage	Tools and methods
Define (D)	Pareto-Lorenz chart
Measure (M)	SPC
Analyse (A)	Ishikawa chart
Improve (I)	Brainstorm
Control (C)	FMEA method 5s

In Fig. 2 shows the frequency occurrence of faults on objects in the period from 2006 to 2013.

In order to further study the graphical image showing the distribution of absolute and relative errors, problems and their causes. Were determined using the following obtained data [7]:
- Identifies a cause of the analyzed phenomenon,
- Causes ranked from most to least which affect the occurrence of faults as well as the estimated contribution each cause has on the whole phenomenon,
- The graph Cartesian coordinates along the x axis plot and in turn causes the posts from the most to least flow,
- Diagram so supplemented. Lorentz curve,
- Take action to eliminate or reduce the impact of the most important causes and improve the analyzed situation.

By using the points mentioned above made listing all the items that include structural defects.

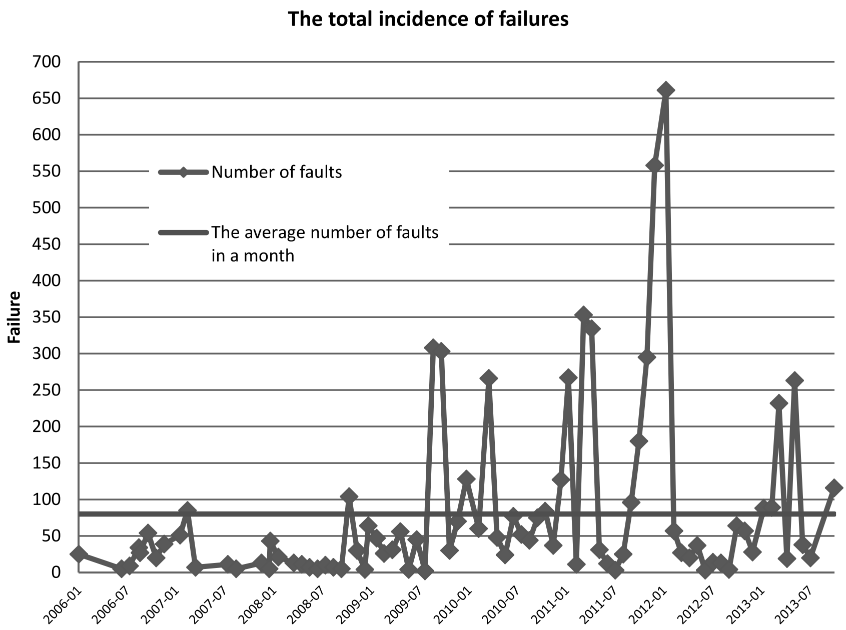

Fig. 2. The incidence of defects during testing (own source)

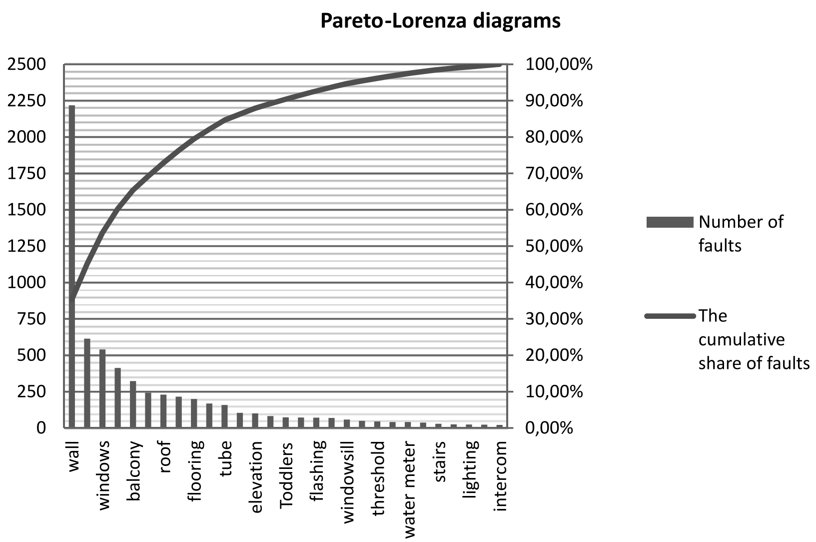

Fig. 3. Diagram Pareto-Lorenz (own source)

From the graph in Fig. 3 we received very important information showing that 20% of the causes affect 80% [8] of the faults. We proved that paying special attention to certain critical structural elements during installation will significantly reduce potential faults. Most defects proved to be associated with walls, windows and radiators. In order to determine a control of works process to limit the occurrence of defects, a scheme, which collects information at checkpoints and verifies quality, was established in the form of measurements.

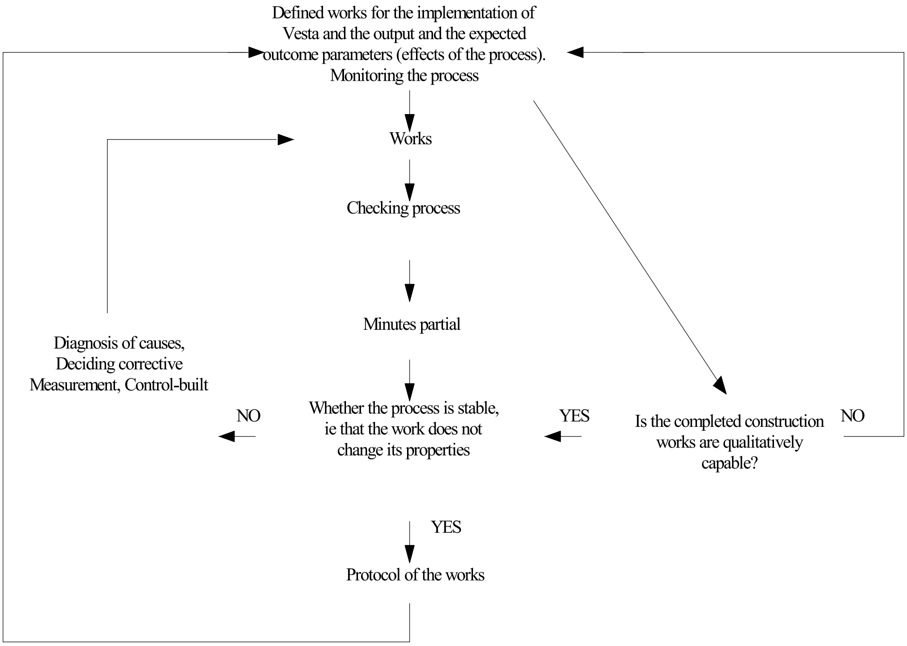

Fig. 4. Process control (own source)

A list of damaged building component was made for an in-depth analysis in order to focus attention on the most neuralgic point, which strongly influences the occurrence of reducing the quality of the works. This was used to analyze the graph [9] Ishikawa, for example, for the analysis of a wall.

The above-mentioned analysis will allow us to delve into the details of significant faults and direct our attention to the element and to improve it, which, together with the other information, forms a whole.

The organization of the construction project is temporary. After completion of the staff transferred to the other contracts, and the whole process is limited in time. Construction is subject to continuous change in the organization of the process. This study was conducted to find potential for improvement in the organization. Based on the approach to achieve perfection in the manufacture and statistical processes used by Motorola [4] was applied to these test solutions in the construction industry.

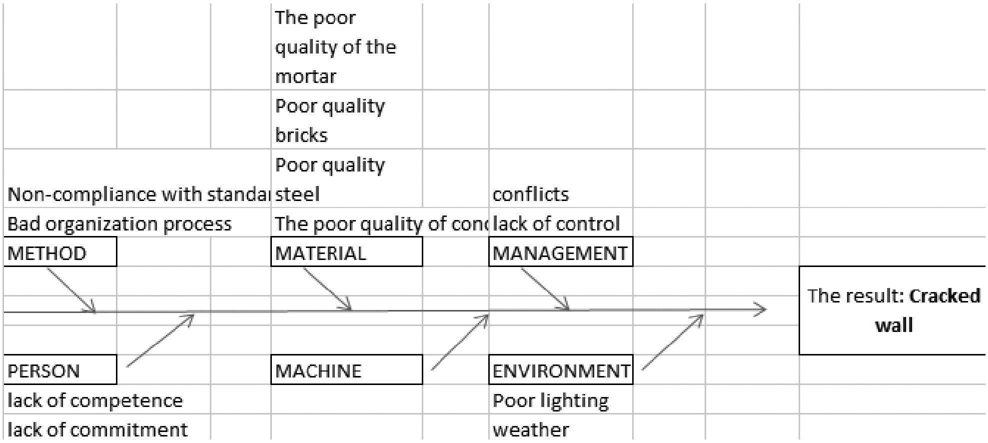

Fig. 5. Ishikawa diagram

Table 3

Summary of sigma level depending on the presence of defects [9]

Sigma Level	Number of defects per million opportunities
1 sigma	690 000
2 sigma	308 537 (companies uncompetitive)
3 sigma	66 807
4 sigma	6 210 (company average)
5 sigma	233
6 sigma	3.4 (world-class companies)

Given the frequency of occurrence could set the level of sigma based on the models [10]:

$$DPU = \frac{D}{U} \tag{1}$$

where:

D – Defects,
U – Units,

$$DPO = \frac{DPU}{OP}\frac{D}{U} \tag{2}$$

where:

OP – Opportunity,

$$DPMO = DPO \cdot 1000\,000 \tag{3}$$

where:

$DPMO$ – Defects Per Million Opportunities,

$$Y = \frac{TOP - D}{TOP} \tag{4}$$

where:

Y – Yield.

For a given set based on sigma level for building elements that have been made and communicated to the operation, in which it revealed flaws. The study classified only erroneous actions and obvious defects.

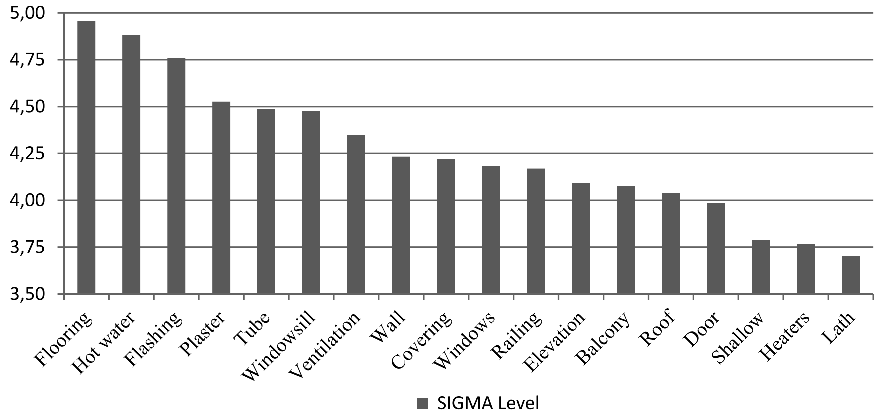

Fig. 6. Level Sigma of the works

SIGMA level provides an informative chart tracking the quality of individually constructed items. Six Sigma method allows you to adjust the properties of the quality to customer requirements [9]. A characteristic feature of this method is to strive for an extremely low level of non-conformity due to the fact that the highest level of Sigma pointed to 3.4 defects per million produced elements of a given type.

3.2. Rating subcontractors

After completing the General Contractors contract with the investor, a survey evaluating the Subcontractors work was carried out. For individual contracts on a scale of 1 to 5 where 1 means very bad score and 5 for very high performance are as follows:

Table 4

Summary of ratings survey subcontractor depending on the quality of execution

Object	Average rating subcontractors on contract	The number of faults on the object
1	3,17	323
2	3,20	684
3	3,14	265
4	3,17	374
5	3,30	39
6	3,40	1425
7	3,46	2148
8	3,45	1579

We see that the subcontractors are on average evaluated considering that the grading scale is 5 steps. With further analysis carried out it was found that when the subcontractor provides a quality service, and above all knows his job, always keeping to the agreed terms, meeting all technical requirements and complying with safety, a very large improvement in the quality and drop occurring faults during operation is later observed.

Table 5

Summary evaluation study comparing the subcontractor, depending on the quality of performance of the contract

Object	Probable number of faults, depending on the quality (grade 5) contractors	Probable number of faults, depending on the low quality (score 1) contractors
1	102	509
2	214	1 069
3	84	422
4	118	590
5	12	59
6	419	2 096
7	621	3 104
8	458	2 288

3. Discussion

In the present statement, we can see, depending on the building element to what level of quality construction works were carried out. Given the level of sigma, we can say that the higher the value, the higher the quality of the item and the lower the likelihood of faults during use and hence the quality of the company is high. The average level of sigma from all five objects is 4.34 it is ok 2,900 units (mistakenly made this million units). From an analysis of the studies received: An average number of around 855 defects per project. Because some descriptions contain several similar defects and sometimes one fault was surrounded by several different industries, the actual number of defects is higher. The costs of removing defects occurring during the study are between 1.2 and 1.3% of production costs. We received a major source of defects by analyzing the received that on average 88% of defects comes from the construction industry 9.5% of the sanitary industry and 2.5% of the electrical industry. The staff of the surveyed construction was not taken into account.

4. Conclusions

This paper presents the test results obtained and carried out for a general national construction company. This paper was designed to show that there are common problems in building components during operation using engineering methods of management. In the study we can say that:

- Successful use of new production engineering methods used in the construction industry is possible,
- information regarding the most faulty building elements will assist decision-makers on contract,
- The higher the level, the higher the sigma class construction company in terms of quality of the works,
- In sum, the total number of defects studied amounted to 419 elements, which amounts to 69.6% of all the possibilities,
- In sum the total number of defects studied for sanitary elements amounted to 109, which is 18.1% of all the possibilities,
- In sum the total number of defects studied for electrical elements amounted to 74 which is 12.3% of all the possibilities.
- Knowledge of the types of defects will ultimately save time and money.

The proposed methodology in this paper a knowledge-based multi-family housing may be one of the most important ideas resulting in the transfer of knowledge gained from past projects. In order to solve this task, production engineering methods are used to direct the main attention of the alternatives as the foundation for new projects.

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