A CRITICAL ANALYSIS OF PROJECT COST ESTIMATION MODELS IN CONSTRUCTION MANAGEMENT LITERATURE

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ABSTRACT

A CRITICAL ANALYSIS OF PROJECT COST ESTIMATION MODELS IN CONSTRUCTION MANAGEMENT LITERATURE

Studies in recent years have shown that the majority of published studies cannot be reproduced. Failure to reproduce the researchs lead to a crisis in the reliability of the study results. The importance and benefits of reproducible research results have been well understood in a number academic fields such as psychology and biomedicine and in turn several steps have been taken to ensure the adequate data sharing in order to reproduce the studies. . The thesis presented herein explores the concept of reproducibility in the context of construction management literature in particular construction cost estimation research. A sample of 227 articles published in project management and construction management journals was analyzed. The research findings reveal that only 3.69% of articles can be reproduced and reproducibility is a major issue in construction management literature. The primary reasons those the reproducibility of the studies difficult include missing data, presentation method, inability to read the graphics and tables, incomplete reporting and explanation errors. It appears that the reliability crisis which has widely acknowledge in a number research fields is also major in the construction management literature.

ÖZET

YAPIM YÖNETİMİ YAZININDA PROJE MALİYET TAHMİN MODELLERİNİN ELEŞTİREL BİR İNCELEMESİ

İnşaat sektöründe, proje yönetimi temel zorluklardan biridir. Projeler belirlenen süre, iş kapsamı ve maliyet aşılmadan bitirilmelidir. Maliyet hem yatırımcılar hem de proje için en temel birleşenlerden biridir. Projelerdeki önemli kararlar maliyete dayanır, o nedenle doğru maliyet tahmini projelerde önemli bir rol oynar. Son zamanlarda, inşaat sektöründe doğru ve kısa sürede maliyet hesabı için bir çok maliyet hesaplama yöntemi geliştirilmektedir.

Tezin ana amacı, maliyet tahmin yöntemlerini proje yönetimi literatürü ve yeniden üretilebilirlik açısından değerlendirerek güvenilirliklerini ve ne kadar doğru sonuç verdiklerini kritik etmektir. Araştırmada, başlıca 23 proje ve inşaat yönetimi dergisinden seçilen 227 makale örneklem olarak seçilerek, belirlenen kriterler(variables) incelenerek araştırmacıların verilerin ne kadarını paylaştığı, sonuçlar konusunda ne kadar şeffaf olduklarının karşılaştırması yapılmaktadır.

Tezin giriş bölümünde, yeniden üretme kavramı ve maliyet hesaplama yöntemleri genel olarak incelenmekte, maliyet tahmini ile ilgili çalışmalarda veri paylaşımı ve yeniden üretme irdelenmekte, tezin amacı, hedefleri ve araştırma soruları ortaya konulmaktadır. Tez çalışmasının ikinci bölümünde, yeniden üretme kavramı tanımları, tarihsel süreci, araştırmalarda veri paylaşımı ve önemi, veri paylaşımını destekleyen bakış açıları ele alınmaktadır. Tezin üçüncü aşamasında, maliyet ve inşaat maliyeti tanımları, maliyet tahmin yöntemlerinin açıklanması, tarihsel süreci ele alınmıştır. Tez çalışmasının dördüncü bölümünde, araştırma analizi ve veri analizi teknikleri açıklanmaktadır. Bu teknikler bağlamında, örneklem seçimi, içerik analizi ve araştırma metodolojisi hakkında detaylar aktarılmaktadır. Tezin son bölümünde, içerik analizi sonuçlarının istatistiki olarak değerlendirilmesi sonucu elde edilen veriler açıklanmaktadır. Araştırma sonuçlarının genel değerlendirmesi yapılarak proje yönetimi literatüründe maliyet hesaplama yöntemi araştırmalarında yeniden üretilme kavramının önemi ve nasıl adapte edilebileceği açıklanmıştır.

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CHAPTER 1

INTRODUCTION

1.1. Reproducibility Concept in Cost Estimation Methods

The construction sector is a complex sector which is involving various uncertainties due to its structure and influenced by many internal and external factors such as economic, social, political. Good management and planning are needed to succeed in this dynamic industry. The success of a construction project depends on the duration of the project, budget, and quality. In this article, we focus on the budget part of the project. Both a client and a project manager want to know the project cost before starting construction works. Knowing the approximate cost is very important for project planning. There are many methods for cost estimation and new methods are being developed. However, even though there are many methods of estimation, it is not known exactly which methods are most likely to work and which are the closest estimation to the real budget. One of the main reasons for this is that it is not possible to be sure whether the published results reflect the truth because the research data are not shared. The issue focuses on in this article is to evaluate whether these studies are reproducible using sharing data for studies on cost estimation methods. The reproducibility of scientific research has seen especially in scientific study fields like psychology, biomedicine, and economics. Recent interest in researchers working in these areas has focused on this topic. Is this concern an issue of project management? Can the cost estimation issue be addressed through reproducibility? What does it mean that research is reproducible? How is made the decision the research reproducible and what is the scope of reproducibility? How does this benefit us? Does the fact that a good article is a reproducible affect the accuracy of that research? When looked at the literature for answers to these questions, there has not enough study in the field of project management even though we are confronted with studies that deal with reproducibility in areas such as biology and health. There have no studies that addressed data based on cost estimation studies and studies investigating the suitability of acquired findings. While answering these questions in this study, also investigates how much of our work on cost estimation methods are reproducible and how consistently the published results are.

1.2. Problem Definition

In psychology and medical literature, there have several concerns about the state of research data in the last few decades. Insufficient data sharing raises doubts about the accuracy of the results. The way to eliminate these doubts and check the accuracy of the research data is to reproduce the study, so the concept of reproducibility appears. In this thesis, examinewhether the studies can be reproduced by using shared data in cost management researches.

This study explores the reproducibility status and data sharing of articles on cost estimation methods. If research cannot be reproduced, some questions arise about the reliability of the study. Some of these questions are listed as follows. Can the articles related to the cost estimation method be reproduced? If not, what are the reasons for not being reproduced? What is the scope of reproducibility? How much of the research data is shared and how? Since there have not many studies in this field, these questions have tried to be answered in this thesis.

When 227 articles on cost estimation methods in 23 selected journals examines, it has seen that they have come a long way in terms of sharing research data and results. Although data sharing policies support and increase thanks to the data sharing policies haveadopted in recent years, most studies still do not share them with sufficient data readers. Lack of data sharing also prevents the reproducibility of the studies.

In general, the study has examined examines the drivers of a possible reliability crisis by documenting the ability to reproduce empirical findings and identifying the reasons for failure to reproduce them. Itexplains the effects of the non-reproduction of findings on studies and showshow it has interpreted and influenced the meaning of repetition and data publishing studies. In conclusion, it gives an idea about whether there are reasons in the cost management literature that may lead to a reliability crisis.

1.3. Scope of the Thesis

This research has focused focuses on the reproducibility of 227 articles about cost estimation methods from the 23 project and construction management journals. The main reasons why the thesis has focused on these articles is that they are (1) published in major journals in project management field and (2) met the criteria for research.

1.4. Aim of the Thesis

The main objectives of the study presented in the thesis are;

- To explore the evolution of reproducibility
- To explain the cost estimation methods
- To examine the concept of reproducibility in the context of cost estimation methods research
- To identify document the ability to reproduce empirical findings and identify the reasons for failure to reproduce them
- To examine how much study data is shared

CHAPTER 2

THEORETICAL FRAMEWORK

2.1. Definition of Reproducibility

The term reproduce was found in a work by Claerbout in the early 1990s. He was one of the first to defined reproducibility, and his principle has been called the Claerbout Principle and has been adopted. Claerbout distinguished the articles by reproducibility or replicability. These terminologies have very close to each other as a meaning. With the spread of the concept of reproducible in all disciplines, some conflicts have emerged in the use of terminology. The requirements and methods of each branch of science to reproduce the research are different, so differences in reproducible definitions began to occur. Or, they used both terms in the same sense because they thought they meant the same situation in both words. There had no interdisciplinary language that describes these terms. Therefore, it has not always clear what researchers use the words reproducible, repeatable, replicable, generalizable to describe (Stark, 2018). Do two scientists using the same term really express the same situation? This was one of the problems that must be solved first. Reproducibility may be empirically, systematically, and conceptually. There had researchers who used terms of repeatability, reliability, robustness, and generalizability instead of reproducibility. (Nature, 2016, vol533). This has usually seen in different fields. To be clear "the criteria for reproducibility may vary widely among scientists". A workshop held in July 2017 to solve the confusion in terminology, and more than a dozen researchers participated in the workshop to create a common terminology (Barba 2018).

Claerbout's supporters Donoho (2009) and Peng (2011) embrace these concepts. According to their point of view; replication is the study that has the same results with different studies and analyses and new data is obtained.

Although King's 'replication standard' requirements (King, 1995) and Claerbout's Reprodubility principles are similar, King uses the term replication in all cases.

Peng (2011) defines reproducibility as the minimum standard used to evaluate scientific claims in the event that the study can not be replicated. The standard of reproducibility is that data and codes are suitable for open access and analysis for use by others. This criterion is not sufficient to replicate the study. Because data and codes are shared, which software is used during the research and in which order it is used to combine the latest research findings, which code is run, and not all stages of the original study are known. In 2011, Science magazine published a special issue with the theme of 'data replication and reproducibility '. And in the introduction, it says that "replication is the confirmation of results from a study independently of another baş the principle and standard of reproducibility are based on it." (Barba, 2018). Peng publishes an article in this special issue, which influences many people in the field of reproducible research. It was one of the most cited articles. In this article, Peng claims that reproducibility is not a powerful criterion for evaluating research results and that he calls it the reproducibility spectrum (Peng, 2011).

Sandve et al. (2013) agree with Peng (2011) that a study would not be reproduced completely, so it was a minimum standard to evaluate the results. Although the terms have not clearly defined in the study, they support the same idea as Claerbout's principles.

LeVeque et al. (2012) say that replicable is to run the same code and obtain the same result in the discussion entitled "Reproducible Research: Tools and Strategies for Scientific Computing". According to them, reproducible is to use our knowledge to create our own code and to check the accuracy of the results.

According to Stodden (2011), reproducibility is an effort by the author to produce all kinds of information independently. Stodden (2013) divides reproducibility into empirical and computational reproducibility. He later adds the concept of statistical reproducibility. According to Stodden et al. (2014), replication was the independent application of experiments and confirmation of results. Replication-related reproducibility was the result of using the same data sets and methods.

Barba (2018) uses a decision tree to classify terminology and divides into two as group A and group B. Group A do not distinguish between reproducibility and replicability. Group B accepts the difference between the two terms and divided it into two. The group called as B1 was the one that uses the same data and methods and has reached the same result. B2 group reaches the same result with different data and methods.

Radder (1996, 2012) defines reproducibility is to obtain the original result by the same methods. Obtaining the same result with different methods was reproducibility. According to him, reproducibility is the necessity to repeat the entire study successfully to test the reliability of the results. Therefore, not only the results but also the course, the experiments, or the software must be done in the same way and should be under control.

Vandewalle et al, (2009) argue that the ability of independent researchers to recreate the study, if all data are available, is called reproducibility.

Goodman et al. (2016) state that there is no standard for terms such as reproducibility, replicability, reliability, robustness, and generalizability. Therefore, they have proposed the new lexicon of reproducibility. According to this data dictionary, reproducibility divides into methods reproducibility (Claerbout and Donohon's definition of reproducibility), results reproducibility (definition of replicability of Peng), and inferential reproducibility.

- Methods Reproducibility: having of sufficient details about the data and method of the study. Thus, the work can be repeated theoretically and in reality by following the same steps. In theory, it is easy, but in practice, it is difficult to provide all the details. The methodological reproducibility of a study is related to the degree "the degree of processing of the raw data, the description of the measurement process, and the completeness of the analytic reporting."
- Results Reproducibility: Repetition of the same data by the stages of the original study by a different group to obtain the same results.
- Inferential Reproducibility: Repetition or re-analysis of a study by another researcher to achieve the same qualitative results. This type of reproducibility is not considered a separate concept. Inferential reproducibility has not seen as different from Results reproducibility, but the two are actually different things. Researchers do not obtain the same results from the same data and may find different results with the same data. The choices we made during this process are effective. (Goodman et al, 2016)

Patil et al. (2016) develop a statistical model. They use this model to define terms and resolve conflicting statements about reproducibility and replicability of studies. Reproducibility is data, code, analysis and reconstruction of different methods to achieve the same results. Replicable is the repetition of the study without changing any variables and results consistent with the first study.

US National Health Institutes defines reproducibility as the ability to obtain supportive results and data to validate a research outcome (Mendoza and Garcia, 2017).

Merriam-Webster's and Wiktionary describes the reproduction as a complete copy with the same criteria, but replication resembles the original despite differences in the study (Osterman and Granell, 2017).

According to Osterman and Granell (2017), reproducibility is related to determining the accuracy of the results of the study using data sets and algorithms in the study. Replicability is to achieve the same results using different data sets and similar methods. Therefore it is more concerned with the development of knowledge.

Olorisade et al., (2017) describe reproducibility as independent duplication of research data to understand, control, and produce information correctly.

Stevens (2017) clearly defines these two terms "replicability is the experiment and collecting new data. Reproducibility is the same analysis using the same code."

According to Stark (2018), the term reproducibility's meaning is different in computational science and biomedical disciplines. In computational science, reproducibility is the existence of sufficient data to allow researchers to obtain their own calculations. In biomedical disciplines, the reproducibility of experiments is to make the same result from the beginning.

Leonelli (2018) claimes that there are many interpretations of the meanings and consequences of the terms reproducibility, replicability, and repeatability in natural sciences, philosophy, and other disciplines. This is not surprising, as all branches have different approaches, concerns and objectives. For example; in the fields of medicine or pharmacology to ensure the safety of experiments and the production of products such as drugs. In computer science it can be defined as reproducibility for different people to rewrite the code, even if the variables change, in a different place. There are two aspects of confusion between the two terms.

After the emergence of these terms, contradictory terminologies began to spread. The term reproducible has been used since the 1990s, and the distinction between reproducible and replicable has been introduced since 2006. The first study which used the term replicability instead of reproducibility has thought to be Drummon (2009). He said that he changed terms that way just because he thought it made sense. Mark Liberman, a professor of linguistics on the subject, argued that definitions other than those have adopted by Claerbout and Peng should be rejected (Barba 2018). But this article by Drummond (2009), many researchers adopted this terminology. Those who adopted this terminology include Casadevall and Fang (2010), Davison (2012), Loscalzo (2012), Cooper et al (2015) (Barba, 2018). In fact, many citations have made to the article. Some of these citations made to criticize contradictory terminology. Drummond (2009) said that researchers working in the field of machine learning have not been able to reproduce their work at least once. Drummond (2009) opposed the claim that reproducible research was distinctive in science and that studies must necessarily be reproducible. The important point of obtaining experimental results is that the irrelevant things are not intentionally reproduced. The experiment should be repeated, not the result. Therefore, it has seen reproducibility as a waste of time. According to Drummond (2009), " reproducibility requires changes, replicability avoids them ". But Drummond (2009) called replicability what other researchers described as reproducibility. According to him, 'reproducibility means to replicate the original experiment and that nothing else will do'. In the concept of reproducibility, only results have similar in the experiment, all other criteria may vary. He claimed that "replicability is a poor substitute for scientific reproducibility". Collecting and sharing all research information in articles is of course a useful endeavor for good reasons, but reproducibility is not one of them (Drummond, 2009).

Crook et al. (2013), adopte the terminology definition of Drummond (2009). They expand these definitions by separating them into four. These terms; internal replicability, external replicability, cross replicability, and reproducibility.

- Internal Replicability is that the study author or another researcher can reproduce the result without making any changes to the knowledge and method.
- External replicability is recreated by another researcher using the same code and data.
- Cross replicability is to run the same study using different software.

The difference between cross replication and reproducibility is not clear.

According to the International Vocabulary of Methodology (Joint Committee for Guides in Metrology, 2006) and ISO 5725-2, the Repeatability of measurement is a short-term study on the same object, in the same working environment, with the same system and data. The reproducibility of measurement, with the same object, using the same measurement procedure results in the same environment that duplicates work is long, variable in these studies may vary. (Plesser, 2018)

The Association for Computing Machinery defines terminology by dividing it into three groups as reproducibility, repeatability, and replicability (Association for

Computing Machinery, 2016). These definitions are suitable for computational science. According to ACM (Plesser, 2018);

- Repeatability: It is the result of following the first study step by step in the same working environment with the same team. The researcher repeats his / her own work.
- Replicability: "The measurement can be obtained with stated precision by a different team using the same measurement procedure, the same measuring system, under the same operating conditions, in the same or a different location on multiple trials."
- "Reproducibility: The measurement can be obtained with stated precision by a different team, a different measuring system, in a different location on multiple trials."

Hameremsh (2007) works on economics and politics. The terminology uses in this field is replication. He extends the term replication to pure replication, statistical replication, and scientific replication. Its distinction is similar to the definitions of The Association for Computing Machinery (ACM).

- Pure replication is reproduction using the same model and data.
- Statistical replication is to produce different data sets using the same model.
- Scientific replication is the replication of different data by different methods (Barba, 2018)

In addition to the academic literature; funders, professional organizations, magazines, and editors have commented on this issue. And it has been seen that the definitions of the fund providers vary in different fields.

2.2. Evaluation of Reproducibility

It is difficult to know the origin of reproducible research. Even though its popularity is based on the last few decades, it is actually as old as scientific research. We have been seen the term reproducibility for a long time in experimental sciences such as chemistry, biology, and physics. In these areas, it is common behavior to share the knowledge of experiments with other researchers. Reproducible research started to developed by researchers working in the field of life sciences. (Vandewalle et al., 2009). The term reproducibility began to become important in the second half of the last century in the field of computational science.

In 1637, Descartes published an article ‘Discourse on the method’. In this article, he said that reproducibility is one of the main components of the scientific method (Vandewalle et al, 2009). Since the 1970s, studies about reproducible research have increased (Goodman et al, 2016).

In 1984, Donald Knuth advocated literate programming. The issues he mentioned have similar ideas to reproducible research. According to him, we needed to develop software to teach computers to do it instead of thinking about what we want to do with computers (Vandewalle et al, 2009).

Jon Claerbout who American geophysicist and seismologist was the first time mentioned the concept of reproducible research. Therefore, he is the pioneer of reproducible research (Barba, 2018). He announced his research which used the term reproducible research for the first time at the meeting of the Society of Exploration Geophysics (SEG) (Barba, 2018) in the Stanford Exploration Project laboratory in 1992 (Vandewalle et al, 2009). He proposed the use of computers for processing and separating seismic motion data. According to Claerbout, reproducibility is using the same data set in the same programs to achieve the same results as the original work. (Plesser, 2018). Since 1990, Claerbout gave importance to the reproducibility of research. He asked his students to write their thesis according to the principles of reproducibility. Because, he defended that after the end of the research, other researchers or readers could be analyzed and calculated all data with a single command without spending extra effort (Barba, 2018). For that purpose, he stored and published all kinds of data of his research. To publish the data, Claerbout developed an automation tool with the Stanford Exploration Project team. Thanks to this tool, readers have able to find themselves in the data environment of the article. In other words, they linked all the calculations and codes of the numerical results to the article so that the readers could be seen how the data was generated during reading. They were also able to test the accuracy of the article by running ready-made software. This study was done about 30 years ago. With today's knowledge and technology, this practice is much easier now, but researchers are still not widely using it (Donoho et al, 2009). The answers to "What is the reproducible research and how it should be?" question has been explained with this study for the first time (Barba, 2018).

After Claerbout, also David L. Donoho who is a professor at Stanford has adopted Claerbout's method in the early 1990s. Another person influenced by Claerbout is Jonathan B. Buckheit. Then, Donoho and Buckheit worked together. Using MatLab, they worked on a tool called as Wavelab. The aim of Donoho was to access data sets, codes, software, tables, research, and all kinds of details on the internet using Matlab (Donoho et al.; 2009). Matlab which a matrix laboratory is the fourth-generation programming language commonly used in positive science and engineering calculations (cadsay.com/matlab). Donoho combined all the data of the articles he had written so far into a single file and has created the WaveLab. Wavelab is a Matlab library. The library is easily accessible from the internet. There are compatible versions with all operatıng systems. This tool is a set of software developed by Claerbout to maintain the principle of reproducibility. A single package contains every information (program, data, documentation, algorithms, how parameters are set during analysis, codes required to duplicate the research). It is the source for reproducing the result and obtaining variables (Buckheit and Donoho, 1995). The purpose of using WaveLab is that MatLab has software capable of manipulating matrices and vectors and WaveLab is resistant to this. Thus, it is ensured that there are no large deviations in the reproduced data. Wavelab is a toolbox specifically has designed to reproduce the results in articles and is the first attempt to have achieved this goal.

Bucheit and Donoho's approach was "An article about computational science in a scientific publication is not the scholarship itself, it is merely advertising of the scholarship. The actual scholarship is the complete software development environment and the complete set of instructions that generated the figures." This approach called Claerbout principles.

Other names influenced by Claerbout and Donoho are Fomel and Hennenfent. They developed this principle in the Madagascar project (Vandewalle et al, 2009). The Madagascar project was an open-source software package. The purpose of this software was to provide an environment for reproducing multidimensional data analysis for large data sets. Thanks to this system, the software codes of the article were linked to the text (Fomel et al., 2013), and the original data, subsequent changes, and calculations were recorded in the transaction history (http://www.ahay.org/wiki/Main_Page). Thus, the results can be reproduced with a single command. The project started in 2003 and was introduced in 2006. Before the software was released, that was before 2010, many people helped to develop the software. It containes data (such as calculation modules, data processing scenarios, and collection of research articles) that helped to reproduce the research results. As of October 2013, the system included data sets of more than 120 surveys (Fomel et al, 2013).

Another scientist affected by this approach is Roger D. Peng. Peng who is a professor of biostatistics conducts research about air pollution, health risk assessment and statistical methods. His studies that mentioned reproducibility in computational science and biostatistical science made a great contribution to the adoption of the method. He also worked to develop the Reproducible Research Archive and R software. Peng enabled reproducible research to reach more people (Peng, 2011). In 2011, his article published in a special issue of Science magazine was effective in this regard (Barba, 2018).

Information sharing, transparency of results, and data are among the most important elements in order to reproduce the research. As mentioned above, after data sharing, many studies have been done about where software, codes and mega data were stored. One of the objectives of reproducibility is to test the accuracy of the research. This can only be done by comparing the original results and the reproduced results. Vandewalle et al. (2007) have worked on comparison problems, time-series predictions, classification and development of datasets. They discussed what is important (dataset, origin, method, etc.) and how to compare algorithms when creating the ideal environment for repeatable research.

After all these studies, articles that studied the case studies on the reproducibility of the research have been published. Two case studies of reproducible research have presented by Marziliano and Barni et al. Barni et al. (2007) examined how the blind sensitivity algorithm becomes a repeatable signal processing(RSP) paradigm. It examined how to write the definitions of the reproduced results, tables, and graphs in accordance with the RSP principle. The good aspects of this algorithm compared to the classical method and the problems that may be encountered are discussed. Pina Marziliano (2007) examined reproducible research signals with a limited rate of innovation in the context of sampling theory. With this sample, the reconstruction of the Dirac pulse flows was the basis for finite signals. He found that new research was also reproducible because the application depends on the flow of Dirac pulses.

In the field of computational science, Claerbout, Donoho, and Peng have been considered pioneers of reproducible research. Their work in the field of reproducible research has also influenced researchers in other fields of science.

In the mid-2000's, reproducible research concept began to see in different areas of science such as social, behavioral, and economic (Peng, 2009). There have been multiple studies reproducible research in different disciplines. Leek and Jager (2016) mentioned some exemplary studies evaluating reproducible research in different fields of science.

Example of studies evaluating reproducible research:

- Ioannidis et al (2009), Repeatability of published microarray gene expression analyses. 18 articles published between 2005 and 2006 were analyzed. Ten articles out of these could not be reproduced due to incomplete data sharing, misunderstanding of graphics, and explanation of software failure.
- Prinz et al (2011), Believe it or not: how much can we rely on published data on potential drug targets?. 67 studies have examined. Necessary data has been shared only %20 of the articles. Data, code, and methods of information were not available.
- Alsheikh-Ali et al (2011), Public availability of published research data in high-impact journals. 500 articles published in 2009 were collected from 50 journals. 9% of them had all the raw data. 44% of articles have supported the data sharing policy, but there was no explanation for data sharing in most articles. He has explained the importance of data and code availability.
- Hothorn and Leisch (2011), Case studies in reproducibility. 100 articles were examined in terms of data and code sharing. Software codes were available in more than 50 percent of the articles. This study was one of the best studies to show the repeatability rate of the studies.
- Nekrutenko and Taylor (2012), Next-generation sequencing data interpretation: enhancing reproducibility and accessibility. 378 papers in 2011 were examined and 50 out of them were selected. Only seven of them had the necessary data to reproduce. In 19 articles, sufficient data on the applications were reached and there was half of the information.
- Stodden et al (2013), Toward reproducible computational research: An empirical analysis of data and code policy have adopted by journals. This paper has focused on 170 high-impact journals for evaluating code and data sharing policy. These journals of 38% had data sharing policies.

These studies' main ideas are that analyzed some research and collecting data for understanding how many studies reproducible. They focused on data and code sharing in studies. Many surveys have shown that it has been seen that these data were not shared or inadequately shared. That's why it did not allowed for reproducibility. Therefore, the reproducibility rate in research was very low.

The researches mentioned above shows that data sharing was a problematic issue in the last 10 years. Therefore studies cannot be reproduced. Realizing this problem, the scientific world started to work on this subject. Developed standards for data sharing to disseminate the philosophy of reproducible research.

As a result, not having access to all of the data and codes, and not reproducing the scientific work, have caused the question of trust about the results of the research. In this case, the reliability of the work or the correctness of the results can not be proved.

2.3. Reproducibility Crisis

The majority of researches were failed to reproduce researchs even with their own experiments. Nature magazine conducted an online survey in which 1576 people participated. According to the results of this survey, 52% of the respondents thought that the research failed to reproduce and that this is a serious crisis regarding the reliability of the studies. Approximately 30% thought that there is no problem in this subject and that even if the research cannot be reproduced, the trust in the work will not be shaken. The inability to reproduce the result leads to the trust problem of many researchers.

The respondents said that the laboratories they have been working on in recent years have taken some steps to improve reproducibility. Some participants said that repetition was not considered because it caused extra time and cost. Even the theoretical work of the repeatability efforts of Biyalog Irakli Loladze said that it can increase the time spent on the project by 30%.

Reproducibility budget is allocated if there is an extreme case. But it also shows that in recent years, is reproducible research is an important issue. For example, if few people from a team working in a laboratory leave the project, the remaining people find it difficult to understand the experiments in which the separated people are working and the project duration is extended. In order to avoid such situations, the information about the studies should be recorded and stored gradually. If this process is not performed, even the same team is forced, it is very difficult for an independent researcher to repeat the results of the study (Baker, 2016).

2.3.1. Why Cannot Researchs Reproducible?

When do examine the researches, the studies in which full data sets and codes shared were in the minority. Some studies have problems accessing the data. Especially in old studies, serious problems have been seen with data storage. One of these is URL-linked link sharing. In this way, shared data is usually short-lived and it is difficult to store for a long time. Therefore, when has been looked at these links, has been seen the warning 'this information is unavailable or no longer available'. This is troublesome for both data sharing and reproducibility (Vandewalle et al, 2009). There are many failures with reproducibility. Many writers have problems reproducing even their own studies. This is because the data is not recorded and stored in a detailed and disciplined way during the research. Other reasons are missing data, inability to read graphics and tables, not to specify which codes are used to run which software and in what order the software runs (Vandewalle et al, 2009).

Reproducibility is based on the detailed storage of all data and codes of all operations performed on a computer. The absence of computer codes is one of the biggest obstacles to the inability to reproduce the work. Software systems do not record motion breakdown. Therefore, we have no information about the codes used during the analysis. For this purpose, more suitable software systems are used for reproducibility (Peng, 2011). Peng (2011) attributes the lack of reproducibility of studies in the field of computational science to the absence of a deep-rooted culture of reproducibility, as in the fields of nature, medicine, and psychology. Another reason he advocates is the lack of an integrated infrastructure for sharing data. The scientific world is technically inadequate in this field. Journals cannot support online materials. Serious problems occur in inserting existing data into written text.

There are some objectives that are able to done to increase the rate of repeatable research. Firstly, the codes which are used in the analysis should be shared regardless of whether they are clean or in good condition (Peng, 2011). Even this version of the codes helps researchers have an idea about the study. Although there is no remarkable improvement for data sharing, it is an encouraging progress. In this regard, the support of publishers is considerably important.

Secondly, data sharing should be requested for the publication of the articles. Storing code and data in a data repository can be costly so most authors do not publish the study's data to avoid this extra cost. But nowadays, there are a lot of free data repositories such as GitHub (http://github.com) and SourceForge (https: //sourceforge.net). These free data repositories enable researchers to store their studies data for the long term and safely without extra cost.

Finally, the data which was collected from authors and studies should be stored in a common repository. Thus, researchers can easily obtain the information they want from the pool, one of the biggest obstacles to the inability to reproducible studies are removed.In order to make researches reproducible, incentive policies should be developed and all stakeholders in this field should work on this issue. To make a point, the fact that a study can be repeated does not indicate that the results of that study are accurate, quality (Peng, 2011).

2.3.2. The Transparency and Openness Promotion (TOP) Committee

In November 2014, a meeting was held at the Virginia Open Science Center by The Transparency and Openness Promotion (TOP) Committee on procedures and policies for publishing journals' research. This committee consisted of authorized persons, editors, and funding agencies working in social and behavioral sciences. The aim of the meeting was to develop standards for open-access policies/practices of journals, to access scientific norms into concrete actions, and to develop incentive structures for researchers to be more open to be reproducible research (Nosek et al, 2015), improved the transparency of the research process and accessible data. This document provides template guidelines for increasing transparency.

The TOP rules contain eight standards that promote openness (https://cos.io/top/). These are standards that make it easier to adopt procedures such as openness, open research culture, open access, data availability in every field, and complement each other. These standards serve as guidelines for authors and publishers and they were published in Science magazine in 2015 as ‘Transparency and Openness Promotion’ guidelines (https://cos.io/top/). Each of the eight standards contains three levels. The standards are modular so that journals can adapt to their policies individually or together. Journals choose the standards they want to apply and the level of implementation for each. Using journals with the same guidance makes it a common standard on the international platform. While it may be difficult for researchers and publishers to publish information systematically, these standards have become easier to understand.

These eight standards are as follow:

- Citation standards
- Data transparency
- Analytic methods (code) transparency
- Research materials transparency
- Design and analysis transparency
- Preregistration of studies
- Preregistration of analysis plans
- Replication

Levels are defined as disclose, require, or verify. Level 1 is the lowest level, designed to encourage researchers to be open and to facilitate the adaptation process. At this level, minimum data sharing is sufficient, for example, to indicate where codes are written in the article. Level 2, this level increased expectations from authors and publishers. More information should be shared. Regarding the adaptation process, at this level, publishers and authors are not required to source costs. Level 3 is the strongest standard. Level 0 is used to compare journals that do not meet transparency standards (Nosek et al, 2015).

A summary of eight standards and three levels is given in the table below. The table is taken from the TOP guidelines website.

As of June 2019, there are more than 1100 journals and organizations that implement one or more TOP standards. A complete list of these magazines and organizations can be found at (osf.io/2sk9f/). It is also a widely used tool for open science with more than 5000 signatories (cos.io/top/).

The signatories acknowledge that they support research to be open, transparent, and reproducible. Some of the signers are Elsevier, SAGE, Wiley, Emerald Publishing, Taylor and Francis, ASCE, etc.

According to data from the TOP Guidelines, the American Society of Civil Engineers (ASCE) is the latest community to implement TOP standards, including ’Data Availability Statements that share data, methods and codes of research. Elsevier brought a consistent transparency policy to its magazines.

Summary of the eight standards and three levels of the TOP guidelines

Levels 1 to 3 are increasingly stringent for each standard. Level 0 offers a comparison that does not meet the standard.

	LEVEL 0	LEVEL 1	LEVEL 2	LEVEL 3
Citation standards	Journal encourages citation of data, code, and materials—or says nothing.	Journal describes citation of data in guidelines to authors with clear rules and examples.	Article provides appropriate citation for data and materials used, consistent with journal's author guidelines.	Article is not published until appropriate citation for data and materials is provided that follows journal's author guidelines.
Data transparency	Journal encourages data sharing—or says nothing.	Article states whether data are available and, if so, where to access them.	Data must be posted to a trusted repository. Exceptions must be identified at article submission.	Data must be posted to a trusted repository, and reported analyses will be reproduced independently before publication.
Analytic methods (code) transparency	Journal encourages code sharing—or says nothing.	Article states whether code is available and, if so, where to access them.	Code must be posted to a trusted repository. Exceptions must be identified at article submission.	Code must be posted to a trusted repository, and reported analyses will be reproduced independently before publication.
Research materials transparency	Journal encourages materials sharing—or says nothing	Article states whether materials are available and, if so, where to access them.	Materials must be posted to a trusted repository. Exceptions must be identified at article submission.	Materials must be posted to a trusted repository, and reported analyses will be reproduced independently before publication.
Design and analysis transparency	Journal encourages design and analysis transparency or says nothing.	Journal articulates design transparency standards.	Journal requires adherence to design transparency standards for review and publication.	Journal requires and enforces adherence to design transparency standards for review and publication.
Preregistration of studies	Journal says nothing.	Journal encourages preregistration of studies and provides link in article to preregistration if it exists.	Journal encourages preregistration of studies and provides link in article and certification of meeting preregistration badge requirements.	Journal requires preregistration of studies and provides link and badge in article to meeting requirements.
Preregistration of analysis plans	Journal says nothing.	Journal encourages preanalysis plans and provides link in article to registered analysis plan if it exists.	Journal encourages preanalysis plans and provides link in article and certification of meeting registered analysis plan badge requirements.	Journal requires preregistration of studies with analysis plans and provides link and badge in article to meeting requirements.
Replication	Journal discourages submission of replication studies—or says nothing.	Journal encourages submission of replication studies.	Journal encourages submission of replication studies and conducts blind review of results.	Journal uses Registered Reports as a submission option for replication studies with peer review before observing the study outcomes.

Figure 2.1. Eight standards and three levels of the TOP guidelines.

2.4. Data Sharing/Data Availability

Data sharing and the availability of study data have a topic of discussion in recent years. This issue became more controversial, especially as reproducible research has become important for the scientific world in the last few decades because studies shows that the most important reason for the failure to reproduce the studies is the lack of sharing or incomplete sharing of the study data.

Articles generally do not share the required details for reproducibility. The reproduction of the research by another team depends on sharing the data as detailed as possible and ease of access. For the last ten years, researchers have been discussing reproduction problems. Every researcher suggested some ideas about how to able to identify and solve problems. To do this, it is necessary to adopt reproducibility as a working routine. Nowadays technology already supports reproducibility. The Internet makes it easy to collect, store, and access information. Authors, public repositories, and publishers should work together to help make access to information easier. There is no guarantee that research can reproduce even after providing all of this. Because, data is shared randomly and incompletely, not by specific arrangement, it can be difficult to read shared charts and tables. These sharings should be shared in certain formats and in a simple and easy to understand manner. FAIR principles adopted to guide how to share such large data. In addition to data sharing, the data format is important for reproducibility, so it should be shared in a common language that all researchers understand (Olorisade et al., 2017).

Data sharing does not have to cover all data of the study. Sharing the minimum data set required to reproduce the results is sufficient. The authors do not have to share the raw data they obtained during the preparatory phase of the study or the data not used in the study. The shared data is sufficient for the independent researcher/reader to understand the study comfortably and to reconcile the data with the results. To provide easy access, the data should be stored in an accessible repository, if not stored they should be made available to editors.

One of the most important factors of not being able to reproduce the studies is missing data information. Missing data is defined as the difference between the data set reached and the planned data set (Soysal et al., 2018). Data sets that do not contain missing data are called full data matrix and data sets with missing data are called missing data matrix. Missing data is a problem affecting all disciplines that collect numerical data. Accurate results cannot be obtained with incomplete analysis or reproduction studies and so the analysis results are going to be inaccurate or estimated results. The quality of the studies using missing data can be degraded, which compromises the reliability of the study.

Data sharing increases the reliability of the studies by making them transparent as well it increases the citation of the article as it increases its visibility. As the number of quotations increases, the credit of the study/credibility increases. In addition, the functionality of the online literature is increasing (Hrynaszkiewicz, 2011) and good scientific practices promote (Elsevier Data Policy).

When sharing study data, if the data size has a small, it can be published as an additional file within the article but if not, it is necessary to store large data files in the repository. Small data sets may also be published in these repositories in accordance with the policies of the institutions and organizations that finance the study, even if the study data is not large enough to be stored in the repository.

By sharing the data appropriately, the data used in the study can continue to exist after the study is completed. Thanks to data sharing, the effort and cost of collecting data are not repeated for other studies.

Data sharing stakeholders are data producers, users, and data archives. There are several ways to share data such as data archives, corporate repositories, and self-dissemination.

- Data archives prevent data formats from obsolescence, data loss, and damage by providing long-term maintenance. In addition, these archives provide sharing data, so the data becomes more discoverable.
- Corporate repositories are data storage and sharing repositories created from the data of the work of corporate staff and students.
- Self-dissemination, on the other hand, is in the form of informal mutual use among researchers or sharing data via web pages.

2.4.1. Why Data is not Shared?

The reasons why researchers do not share data are as follows:

- Data sharing is a time-comsuming task
- Data sharing means additional cost. Researchers don't want to spend it because the project budget is limited
- Sharing data is not usefull,
- Loss of domination of data
- Probability of errors in research work
- Possibility of finding different results from other researchers' own results,
- Concern that data abuse, that it may provide unfair benefit from the data,
- Sharing data with the public contains objectionable information,
- The possibility of sharing information with third parties adversely affecting participants and causing difficulties in data collection,
- The person who produces the data thinks that the data is bad and that the data is not of the quality to be shared,

- Anonymity of data owners
- Lack of encouragement of data sharing

2.4.2. Benefits of Data Sharing

According to ASCE Library, the benefits of data sharing are "discoverability, interdisciplinary and preservation". Sharing research data in a repository (such as creating a DOI address) with open access increases the visibility of the study. It may give the opportunity to carry out other studies together with employees in different fields. Long-term access can be achieved by storing study results in data stores..

There are four reasons for sharing research data. These are (1) reproduce or verify research, (2) making the results of publicly funded research publicly available, (3) allowing others to ask new questions about existing data, (4) and improving research and innovation (Borgman,2012).

2.4.3. Data Sharing Policy of Journals

The fact that an article contains a data availability statement indicates that the article's data is freely and permanently available on the Internet. In recent years, many approaches have been adopted to support and promote data sharing (Hrynaszkiewicz, 2011).

Nowadays, many publishers adopted data sharing policies and aligned them with their own policies. Some of these publishers are Elsevier, ASCE, Emerald, Wiley, Taylor and Francis, SAGE Publishing, NRC Research Press, Springer, and Nature.

The section of the 'Data Availability Statement' of the articles has recently become mandatory in some journals. It is written before the Acknowledge section. There are some ready-made statements that journals have prepared for this section. These statements are explanations about how much of the data in the study will be shared and where these data will be accessed. The authors select the appropriate statement and share the data accordingly.

The Journal of Construction Engineering and Management (JECM) is the first construction-oriented journal that asks the authors for a data availability statement. The Data Availability Statement is a statement that tells you where the research findings and any digital data, code, or software can access. This magazine offers the authors five alternatives to choose resources.

CHAPTER 3

COST ESTIMATION METHODS IN CONSTRUCTION INDUSTRY

The construction sector is a complex sector which is involving various uncertainties due to its structure and influenced by many internal and external factors such as economic, social, political. The success of construction projects exposed to such internal and external factors depends on the right targets being set and the efficient use of resources to achieve the required quality without exceeding the time and budget limits envisaged. Therefore, accurate cost estimation and control is an important component of success in construction projects.

The construction sector is different from the other sectors in terms of the physical structure of the structural structure and the resulting product. As with the industrial area, it is important to create a prototype for a new product, to test the function and cost of the product in question, to detect and eliminate problems that may arise when the actual product is manufactured or sold. The product emerging in the construction sector; it is not economical or practical to construct a prototype because it is large-scale, high-cost, and unique to one time (Seyyar, 2000). At this point, at the beginning phase of the construction projects, determining all the risk factors and making the most accurate predictions are of great importance in order to stay within the specified scope and success of the project.

3.1. Definitions of Cost Estimates

3.1.1. Cost

Cost is the expense of remuneration for obtaining goods and services (Şirincan, 2005). Cost is the sum of the expenditures made to obtain a product. Expenditure on all production inputs is the cost (Kanıt and Baykan, 2004). Cost is the value measured by the currency of all the goods and services consumed for the main activity of an operator or for the purpose of basic operation (Kuruoğlu, 2003).

Cost is the sum of the expenditures made for the goods or services obtained. Spending; the money paid by the entity for any purpose, the transferred asset, the expense of the borrowed money.

3.1.2. Construction Cost

The construction costs are all kinds of goods, materials, human resources, and the provision of financial services used in the process from the design stage to the delivery stage of creating a structure (Şirincan, 2005).

The construction cost is the sum of all the expenses in the process from the feasibility stage to the use stage of a building. The construction approximate cost is the determination of the cost of all work items, resources, and services required for the implementation of the project in the specified time and quality in the process following the design phase (Tokalakoğlu, 2010).

3.1.3. Estimating

Estimation is defined as the judgment of the project manager on the inputs and outputs of the project based on the experience and data collected (Project Management Institute, 2008).

3.1.4. Cost Estimation

Cost estimation is the development of the required budget by providing necessary financial resources for executing a project properly and completing the works (Project Managment Institute, 2000).

The cost estimate can be defined as the short term estimate of the actual cost of a structure under certain conditions (Kanıt and Baykan, 2004).

Cost estimation is at the forefront of cost management work and can be defined as the technical process for determining the total costs of all work items using project information and resources under specified conditions during the specified period (Seyyar, 2000).

3.2. Process of Cost Estimation

The construction sector differs from other sectors due to its general structure and the physical structure of the resulting product. It is impossible to form the prototype of the final product, to develop the product over this prototype, to see the problems that may occur, and to calculate the cost based on the prototype. The resulting product in the construction sector is a one-time, long-term and high-cost product (Seyyar, 2000). For this reason, cost estimation made in the early stages of the construction projects is critical. The construction sector is a competitive sector. In this competitive environment, cost estimation should be made quickly and accurately in a job where high construction costs and variables and risk factors are high (Tokalakoğlu, 2010). False, unrealistic cost estimates are not desirable for both the client and the contractor as they cause serious material damage.

Most decisions are decided during the design phase in construction projects. Early cost estimation at this stage helps the project manager to make basic decisions and supports it (Arafa and Alqedra, 2011). The project manager makes use of former project data in his / her own experience and some estimation methods while making cost estimation. There are a lot of cost estimation methods from traditional methods to machine learning systems used in various stages of the project (Arafa and Alqedra, 2011).

Before the cost estimate, the functional and economic requests of the owner, the customer, and their limitations are determined. It is difficult to determine how much the customer wants to spend and to balance the budget and cost and quality factors that are considered. The customer's budget is effective in determining the size and quality of building projects. The same variables also affect cost estimation. In other words, the cost is formed in line with the decisions made at this stage. Customers usually want to know the approximate cost before starting the project. Historical data comes into play here and a cost is given based on the present value of previous projects. Furthermore, one of the fast cost estimation methods is the cost obtained by multiplying the building area and the approximate unit area cost. Although this method is fast, it is not a reliable method (Geçim, 2015). The estimation process has some inputs and outputs. Construction projects are projects with high-risk factors. An unexpected situation may override all assumptions and cause the cost account to fail. In these cases, past projects are good guides for us. In order to make an accurate estimation, it is necessary to benefit from the experiences of past projects. Past experiences are used to make inferences about the future.

In the later stages of the project, the business items and the project details increase, which leads to changes in project cost. In order to prevent this situation, proceeding within the framework of the cost estimate made during the design phase ensures that the planned cost is not exceeded. Cost control can be repeated at various stages of the project in order to carry out the project budget in a controlled manner. There are three types of the cost identified at different stages of the design phase. These stages are the design phase and the implementation project stage.

In the design phase, preliminary cost estimation is prepared when the preliminary project is prepared, cost estimation is made when the final project is prepared, and approximate cost calculation is made when the application project documents are created (Tokalakoğlu, 2010). Preliminary cost estimations are estimates made to evaluate project alternatives and to decide the final design. At the design stage, when all components of the project are formed and mechanical, static, and electrical projects are prepared, the cost estimate is repeated (Çelik, 2006). Cost estimates for tender projects are generally the most realistic estimates since they are made on completed projects (Çelik, 2006).

In the implementation project stage, the project is now completely designed, all kinds of details are drawn, material selection and specifications are prepared. Cost estimation at this stage is made using real market prices. Thus, it gives the most useful and accurate estimation (Tokalakoglu, 2010; Ökten, 1994).

3.2.1. Purpose of Cost Estimation

The purpose of cost estimation is to ensure that a service or product is realized in limited time and quality by using limited resources (Seyyar, 2000). At the same time, the determination of the construction cost, planning, and keeping the cost under control during the construction is among the objectives (Kanıt and Baykan, 2004). The approximate cost of the structure is the same for the purpose of calculating. The final objective is to determine the cost spent at the end of the project based on the decisions taken during the design phase of the construction projects (Tokalakoglu, 2010).

According to Ashworth (1998), the purpose of cost control is to limit the customer's expenditures within the appropriateness of the conditions, to create a spending plan by allocating the budget in a balanced way between business items and to provide a project of material value for customers (Kanıt and Baykan, 2004).

There are many factors affecting the cost of construction projects. Risks that may occur during construction, deficiencies in the project, material selection, contract articles, environmental conditions are just some of them. It was found that most of the cost estimation methods do not take these factors into account when making cost estimation (Elhag and Boussabaine, 1998). Ignoring these factors, which seriously affect the cost, causes the estimation to lose its accuracy and realism.

3.2.2. Cost Estimation Factors

There are many factors that affect cost estimation. Elfaki et al. (2014) have grouped under two headings as estimator-related factors and project-related factors.

- Factor-based factors vary from person to person, even from country to country. Because the estimator makes the estimation by evaluating the economy, local practices, and the pros and cons of the project in his own country based on his personal experience.
- Project-related factors: Factors related to the project If the most realistic result are desired that definitely affects the cost, need to make an estimate without even considering one. These factors are project size, type of project, material cost, geographical situations, and area conditions, type of client, scope change, project duration, types of bidding, project information, and market condition (Elfaki et al, 2014; Andom, 2015).

3.3. Construction Cost Estimation Methods

The customers always want to know what the total cost would be before starting to build a new structure. Until the early nineteenth century, a rough estimate was sufficient to meet this need, since the scarcity of resources did not became a major problem (Geçim, 2015).

For the first time in the 1950s, the notion of prediction, which emerged in Europe as simple planning of public affairs, began to be classified as a result of research and development work carried out after the 1980s.

With the Industrial Revolution, the importance given to cost estimation and cost control in order to stay within these estimation limits has started to increase gradually. The reasons for this are that (i) technological complexity of the project has increased, (ii) the idea of the making profit and cost awareness has increased, (iii) the traditional economic and social order becomes more mature and dynamic and (iv) the building's needs has increasing day by day (Geçim, 2015).

There are many methods that can be used for cost estimation. It is expected that the methods used will be fast, cheap, and reliable. If the processed data is open to updating, the resulting cost data should be easily available to the designer, employer, and contractor. Cost estimation methods are regard to the design variables, construction methods, the timing of construction processes, and various properties related to the structure (Saner, 1993).

The three main elements of construction projects are time, cost, and quality. Good planning of these three factors is important for the success of the project. If the project completed within the specified time and budget has reached the desired quality, it means that it successfully implemented. Therefore, the time and cost estimation before the construction of the projects are a necessary and important stage. During the preliminary cost estimation phase of the construction projects, the estimator does not have detailed data such as detailed and full set drawings and material information. The estimator makes estimates based on previous similar project data and own experience. Some methods are needed to facilitate and accelerate cost estimation, and various cost calculation methods were developed. Thanks to these methods, the factors that affect the cost are taken under control, and more accurate results are obtained. (Uğur et al, 2011).

The features that a successful cost calculation method should have; it should be appropriate to the project process, the information about the project should be accurate and sufficient and the information to be entered into the model should be processed up-to-date in order not to be affected by the time factor. At the same time, the model should be available to everyone involved in the project (Uğur et al, 2011).

The primary purpose of cost estimation is to make a reliable cost estimate. The desired cost may vary depending on the project, changes made and the customer's request. The advantage of estimation methods, tolerable deviations inaccuracy of results, ease of application, and rapid results are the points to be considered when selecting the method (Elhag and Boussabaine, 1998).

According to Geçim (2015), there are some important points to be considered in estimation methods. Firstly, the data should be available. There is no point in using a complex method if there is incomplete and insufficient data that are not sure of its accuracy. A realistic and reliable cost estimate cannot be made. Secondly, consistency and diversity of data should be ensured. Another point is the time interval also affects the accuracy of the prediction. Recent estimates are more likely to be accurate. And also the degree of accuracy and reliability allows the calculation of probabilities by risk analysis. The last one is that estimates should be open-minded about the future.

Construction cost estimation methods, in general, are approximate cost estimation methods and detailed cost estimation methods. Approximate cost estimation methods which are prepared in a short period of time and which can roughly estimate the cost. Detailed cost estimating methods are based on the determination of the quantities and costs of all the components required for the work to be performed.

There is no single correct classification of these methods. When have done a literature search, can be seen that the authors classify them according to their own.

Software cost calculation is a challenging calculation method. Before the cost calculation, the project to be calculated should be defined and understood. In the early stages of the project such as the design phase, has less input-output, so the estimate is more accurate. The early cost calculation helps to determine the scope of the project and to conduct it properly. Software cost calculations are based on historical data. The software determines the cost of the project entered by analyzing that data so there should be no missing, incorrect, non-continuous data.

Tripathi et al. (2016), software calculation methods are divided into three as algorithmic methods, non-algorithmic methods, and machine learning methods.

- Algorithmic Methods: They are models based on mathematical equations. Equations based on research and historical data such as a number of functions, language, design methodology, risk assessment. There are many methods developed using algorithmic methods such as COCOMO Model, Putnam Model, Function Point Analysis, Linear Models, Seer-sem Model, etc.

- Non-algortihmic Methods; are prediction methods using data sets of past projects. Non-algorithmic methods; expert judgment method, estimating by analogy, Parkinson's law, price-to-win, top-down estimating method, bottom-up estimating method.

- Meachine- learning Methods: Statistical methods are used in machine learning methods. During forecasting, they adapt the equations according to the project and make estimates by repeating the data and results. Therefore, it may be a more suitable method than other methods. Machine learning methods are neural networks, fuzzy methods, etc.

One cannot say those cost estimation methods are better than the other. Each method has advantages and disadvantages. Considering these must be found and used the most appropriate method for the project. Algorithmic methods are based on mathematical equations. They need a lot of data to estimate. Non-algorithmic methods conclude by analyzing the data of similar project types previously made. Having sufficient and significant historical data is enough to predict. According to Tripathi et al. (2016), algorithmic methods can give reliable results when there is sufficient data and non-algorithmic methods give faster results than other methods so it will be a reliable and fast method for cost estimation of similar projects.

Kanıt and Baykan (2004) categorized cost estimation methods as (1) quantity-based methods, (2) mathematical models, and (3) computer-based models.

Quantity-based methods are based on previous project data. Based on the unit, quantity, cube, area, and coat methods are some of the methods of quantity-based methods. Methods based on mathematical models reach estimation by examining the relationship between the variables. For example; regression models are one of the mathematical models. Computer-based models can define as methods with artificial intelligence approaches. They make cost estimation by using a large database and also decide the last decision together with the user (Kanıt and Baykan, 2004).

According to Çelik (2005), can be classified generally accepted methods into three main categories.

1. Statistical-Probability Analyzes: Unit Method, Volume Method, Area Method, Floor Shell Method, Causal Estimation Methods, Parametric Methods Based on Regression Analysis, Cost Estimation Methods Based on Analysis of Functional Elements, Expected Value Method, Range Method, Model, Simulation Method (Stochastic Modeller), Cost Estimation Method with Dimensionless Sizes, Ratio (Factor) Method, Estimation Method with Cost-Capacity Factors

2. Comparison with Similar Projects*:* Early Cost Estimation, Comparison Method with Element Based Cost Analysis, First (Pre) Estimation Method, RS Means m^2 Estimation Method Based on Floor Area, RS Means m^2 Commercial Building Model Software, RS Means Housing Model Software, RS Means Unit Cost Multiplier, Total Cost Multiplier Method, etc.

3. Artificial Intelligence Techniques: Estimation Method with Artificial Neural Networks, Fuzzy Logic Method, Genetic Algorithms, Forecasting with Expert Systems, Case-Based Reasoning

Elfaki et al. (2014) examined cost estimation methods with intelligence techniques under five main topics. These are; (1) machine-learning systems, (2) knowledge-based systems, (3) evolutionary systems, (4) agent-based systems, and (5) hybrid systems.

1. Machine-learning Systems: It is an algorithm used to estimate the results of machine-learning data and provides accurate and reliable results. It provides more data collection for statistical analysis by continuously updating the output data while evaluating the input data and creating the algorithm. Elfaki et al. (2014) claimed that these systems are able to cope with uncertainty and incomplete data problems, and can also successfully interpret past project data through statistical analysis. The most widely used techniques are artificial neural networks (ANN) and support vector machines (SVM).

2. Knowledge-based Systems: It is all kinds of techniques that include logical rules and that can be defined as a branch of artificial intelligence. It helps experts make decisions. According to Elfaki et al. (2014), the strongest aspect is the ability to justify every result. Although it is easy to use the program, the ability to learn within the program itself is poor. It does not feature the ability to analyze and update the data in machine-learning systems. Case-based reasoning and expert systems are the most preferred methods of this category.

3. Evolutionary Systems: It is one of the intelligent systems based on intuition using evolutionary algorithms, which is the sub-branch of artificial intelligence studies. Its algorithm is based on randomness. Elfaki et al.(2014) claimed that they are optimization tools used to solve complex problems where information is lacking and uncertainties are high.

4. Agent-based Systems: It is a product of artificial intelligence that enables simulation by using complex software units that are autonomous and capable of

decision making up to a certain level. It is difficult to generalize the results in projects where these systems are used (Elfaki et al, 2014).

5. Hybrid Systems: Hybrid systems are concept cost estimation methods that include all kinds of cost estimation methods. It is the use of two or more methods to overcome the limitation of a single method. It is one of the most assured methods for achieving realistic predictions.

According to Elhag and Boussabaine (1998), functional unit, surface area, surface environment, element analysis, cube method, interpolation methods are weak cost estimation methods. These methods fail to evaluate factors such as customer, project, consultant, design features, contract procedures, environmental conditions, and market characteristics and fail to provide accurate results. Models such as Linear / Dynamic Programming, Regression, Analysis, Simulation / Risk Analysis, and Expert Systems (ES) are not effective methods in complex projects. Excess of variables, uncertainties in projects, complex relationships between inputs and outputs are the methods to solve problems.

CHAPTER 4

RESEARCH METHODOLOGY

4.1. Introduction

The objective of this chapter is to explain the research method used in this thesis. This research started by questioning how functional/reliable cost estimation methods are compared to traditional cost calculation methods. When the project management literature has been examined, it has seen that there are many cost estimation methods developed to facilitate cost estimation, and all of them claimed that they are more accurate than the traditional method and have many advantages such as shortening the estimation time. In addition, when observed studies, have been seen generally studies compare the two methods. However, most of the articles have shown that the data related to these studies were not shared. The only way to confirm these claims is to reproduce the study results. Therefore, the thesis study examines two different main topics as reproducibility and cost estimation methods.

In many kinds of literature, such as psychology, economics, biomedicine, there are important concerns about the status and reliability of the study results. In the literature, it has been found that most articles cannot be reproduced due to insufficient data. There is no enough work in the field of project management.

In this thesis, it investigates whether cost estimation methods can be reproduced. Reproducibility is the same result obtained by repeating the same study data with the same or different methods. Failure to reproduce the operating data results in reliability concerns. The thesis was sought answers to these questions.

- Can the findings be reproduced in the cost estimation field?
- Why can't it be reproduced?
- What data is shared and how is it reported?

So, this thesis subject has focused on questioning the reliability of cost estimation methods in project management literature and how much studies are reproducible.

4.2. Research Strategy

First of all, a literature review was conducted to explore the concept of reproducibility in general literature. As a result of the research, were seen research about reproducibility is mostly done in fields such as medicine, nature, psychology. Besides that limited researches were found in the construction sector and project management literature.

Secondly, a literature review was conducted to explore cost estimation methods, the other main subject of the thesis, in project management literature. Related terms are defined.

The third stage was data collection. In this section, articles about cost estimation published in journals determined by the Scopus database were examined. Selected journals are the most prestigious and have extensive research sources in the field of project management and construction management. These articles were examined to document whether the study was reproducible. This thesis gives an idea about whether there is a trust crisis created by the inability to reproduce in cost management, the reasons why research is not reproducible, and the results.

4.3. Research Sample

This research demonstrates the problem of lack of data in articles on cost calculation methods, their inability to reproduce, and the reliability of methods in the context of a particular research flow. How important this problem is and how it contributes to the development of cost calculation methods are important questions. In order to find answers to these questions, were completed a content analysis of articles on cost calculation methods published in leading project management journals.

Sample

In order to determine the optimal properties of the sample, previous studies were reviewed and the data required for reproducibility were investigated. At the end of this research, it was decided that firstly prestigious journals in the field of project management should be selected. The articles selected in these journals would be related to the cost estimation method. The process of selecting journals and articles proceeded as follows.

Firstly, the academic databases to be used for article selection were determined. Scopus, ASCE Library, Emerald, Wiley Online Library, and Taylor & Francis Online, and WEB were used. The keyword ‘construction cost estimation’ was selected to use when searching in Scopus. After researching this keyword, 3,733 results came up. Some restrictions were introduced in accordance with the criteria sought. The research was limited to as document type article, source type journal, and language English. At the end of this limitation, 1,803 documents remained. At this point, magazine selection was made. 24 of the leading journals in the field of project management were selected. These magazines are *Journal of Construction Engineering and Management, Automation in Construction, Construction Management and Economics, Cost Engineering Morgantown West Virginia, Canadian Journal of Civil Engineering, KSCE Journal of Civil Engineer, Engineering, Construction and Architectural Management, Journal of Computing in Civil Engineering, International Journal of Project Management, Journal of Civil Engineering and Management, Journal of Management in Engineering, International Journal of Civil Engineering and Technology, International Journal of Construction Management, Journal of Performance of Constructed Facilities, Building and Environment, Construction Innovation, Computer Aided Civil and Infrastructure Engineering, EMJ Engineering Management Journal, Journal of Architectural Engineering, Journal of Asian Architecture and Building Engineering Management.* The full list of journals is shown in the table below.

H-indexes of the journals in which the articles forming the basis of the research were selected also were examined. Besides the selection of journals with high H-index in terms of the reputation and reliability of the journals, the h-index scores of the journals vary between 14 and 124 and were determined in order to make the research comprehensive.

The H-index is a number that aims to represent both the efficiency and impact of a particular scientist or information, or a group of scientists or academics, or a publication and journal. It means that H-index is an index for measuring an individual's scientific research output and it tries to measure both a scientist's scientific efficiency and apparent scientific impact. The index is based on the set of cited articles and citations (Wikipedia).

Table 4.1. Number of available articles in journals.

CODE	JOURNAL NAME	NUMBER OF ARTICLE
1	Journal of Construction Engineering and Management	99
2	Automation in Construction	46
3	Construction Management and Economics	43
4	Cost Engineering Morgantown West Virginia	35
5	Canadian Journal of Civil Engineering	21
6	KSCE Journal of Civil Engineerig	21
7	Engineering, Construction and Architectural Management	19
8	Journal of Computing in Civil Engineering	18
9	International Journal of Project Management	17
10	Journal of Civil Engineering and Management	17
11	Journal of Management in Engineering	16
12	International Journal of Civil Engineering and Technology	13
13	International Journal of Construction Management	8
14	Journal of Performance of Constructed Facilities	8
15	Building and Environment	7
16	Construction Innovation	6
17	Computer Aided Civil and Infrastructure Engineering	5
18	Joournal of Financial Management of Property and Construction	5
19	Journal of Information Technology in Construction	5
20	Transportation Research Record	5
21	EMJ Engineering Management Journal	4
22	Journal of Architectural Engineering	4
23	Journal of Asian Architecture and Building Engineering	4
24	Electronic Journal of Information Technology in Construction	3
TOTAL		429

Table 4.2. H-index scores of the journals.

CODE	JOURNAL NAME	H INDEX
1	Building and Environment	124
2	International Journal of Project Management	121
3	Journal of Construction Engineering and Management	95
4	Automation in Construction	95
5	Transportation Research Record	94
6	Construction Management and Economics	81
7	Computer Aided Civil and Infrastructure Engineering	68
8	Journal of Computing in Civil Engineering	64
9	Journal of Management in Engineering	55
10	Canadian Journal of Civil Engineering	53
11	Engineering, Construction and Architectural Management	49
12	Journal of Performance of Constructed Facilities	41
13	Journal of Civil Engineering and Management	38
14	Electronic Journal of Information Technology in Construction	38
15	Journal of Information Technology in Construction	38
16	EMJ Engineering Management Journal	32
17	Construction Innovation	32
18	Journal of Architectural Engineering	30
19	KSCE Journal of Civil Engineering	26
20	Cost Engineering Morgantown West Virginia	19
21	International Journal of Civil Engineering and Technology	18
22	Joournal of Financial Management of Property and Construction	17
23	Journal of Asian Architecture and Building Engineering	16
24	International Journal of Construction Management	14

All articles published without regard to other criteria were selected for review. No limitation was made regarding the time, the results were based on the dates. It was defined how repeatability has changed over time and how the development of data sharing has evolved thanks to the wide time span. After the journal selection, the number of articles to be examined was determined as 429. Since 41 articles were not stored on digital media, these articles could not be accessed and were excluded from the research. The number of articles to be examined was determined as 388. Since the main research topic is cost calculation methods, 388 articles were reviewed one by one, and inclusion and exclusion decisions and articles to be used in the study were selected. The abstract and keyword sections of the articles were first examined. In the keywords section, words such as cost estimation, cost, estimation methods, construction cost, forecasting were searched. In the summary section, it was examined whether the article is related to construction cost calculation methods. Thus, preselection was made. Then, the whole research was read and it was decided whether the study was related to the cost calculation method. At the end of the study, it was decided that 161 articles did not meet the criteria and these were removed. The remaining sample size was 227. In this review, one of the selected journals, 'Journal of Performance of Constructed Facilities', were excluded from the study due to the lack of an article on cost calculation. Thus, 23 journals and 227 articles were used for the research.

The following table (Table 4.3) shows that all the number of articles in each of the 24 journals, the number of articles which is available, and the number of articles related to construction cost estimation and irrelevant articles.

Table 4.3. Relevant and irrelevant articles realted to cost estimation methods.

CODE	JOURNAL NAME	NUMBER OF ARTICLE	NUMBER OF AVAILABLE ARTICLE	NUMBER OF RELEVANT ARTICLES	NUMBER OF IRRELEVANT ARTICLES
1	Journal of Construction Engineering and Management	99	99	62	37
2	Automation in Construction	46	46	23	23
3	Construction Management and Economics	43	43	29	14
4	Cost Engineering Morgantown West Virginia	35	7	5	2
5	Canadian Journal of Civil Engineering	21	21	13	8
6	KSCE Journal of Civil Engineerig	21	21	14	7
7	Engineering, Construction and Architectural Management	19	19	11	8
8	Journal of Computing in Civil Engineering	18	18	5	13
9	International Journal of Project Management	17	17	9	8
10	Journal of Civil Engineering and Management	17	17	11	6
11	Journal of Management in Engineering	16	16	14	2
12	International Journal of Civil Engineering and Technology	13	2	2	0
13	International Journal of Construction Management	8	8	5	3
14	Journal of Performance of Constructed Facilities	8	8	0	8
15	Building and Environment	7	7	4	3
16	Construction Innovation	6	6	2	4
17	Computer Aided Civil and Infrastructure Engineering	5	5	2	3
18	Joournal of Financial Management of Property and Construction	5	5	4	1
19	Journal of Information Technology in Construction	5	5	1	4
20	Transportation Research Record	5	3	2	1
21	EMJ Engineering Management Journal	4	4	3	1
22	Journal of Architectural Engineering	4	4	1	3
23	Journal of Asian Architecture and Building Engineering	4	4	3	1
24	Electronic Journal of Information Technology in Construction	3	3	2	1
TOTAL		429	388	227	161

The sample frame divides into two groups as those published between 1984-2009 and 2010- 2019. It was defined to determine if the repeatability of the findings changed over time and included articles that could reflect more recent methodological practices. Only articles that examine cost estimation models were kept. At the end of this process, 227 articles were defined (92 articles from 1984 to 2009 and 135 articles from 2010 to 2013). Then each article was examined to determine whether the means, standard deviations, correlation tables, and sample size data required to reproduce the results were shared. 227 articles are defined in Appendix A in the annexes. In addition to these variables, the descriptive data (mean, median, SD, min. And max. Values), raw data, modified data, diagnostic tests, skewness and kurtosis values as well as the reproducibility of the articles in order to better understand the size of the data sharing in the articles. Since we reviewed the information on the data availability statement, it was also examined in the articles. When all data were reported, the values were normalized and organized into matrices.

After collecting the necessary data, the journals examined were listed from those who published the most articles on cost estimation methods to those who published the least articles. This ranking was made to cover all articles, that is, a ranking was made according to the articles published from 1984 to 2019. In this ranking, 8 journals with the most articles were selected and detailed analysis was made through them. The first 3 journals selected were in the top 3 in the ranking from 1984 to 2009 and from 2010 to 2019. The ranking from 2010 to 2019 was the same as the overall ranking. The reason for this is that the studies with cost calculation methods have increased in the last 10 years. However, two of the journals that remained in the ranking from 1984 to 2009 are in the top eight. The remaining journals were held to see the development of journals on this subject. In this case, the analysis was made on 65 articles from 1984 to 2009 and 111 articles from 2010 to 2019.

Table 4.4. Number of shared descriptive variables analysis for 1984 – 2019 period.

				REPORTED VALUES (1984 - 2019)											
CODE	JOURNAL NAME	H INDEX	NUMBER OF ARTICLE	MEAN	MEDIAN VALUE	STD. DEV.	SKEWNESS	KURTOSIS	DIAGNOSTIC TESTS	FULL CORRELATION TABLE	NUMBER OF RAW VARIABLES	NUMBER OF TRANSFORMED VARIABLE	REPRODUCABLE	DATA AVAILABILITY STATEMENT	CODE
1	Journal of Construction Engineering and Management	95	62	12	3	10	1	1	3	8	3	10	3	9	14
2	Construction Management and Economics	81	29	10	5	10	3	3	3	7	3	7	3	0	3
3	Automation in Construction	95	23	2	1	4	0	0	0	1	0	0	0	0	14
4	KSCE Journal of Civil Engineerig	26	14	3	0	1	0	0	0	2	1	0	0	0	3
5	Journal of Management in Engineering	55	14	4	2	5	1	1	0	3	0	4	1	0	2
6	Canadian Journal of Civil Engineering	53	13	4	0	4	1	1	1	1	0	1	0	0	1
7	Engineering, Construction and Architectural Management	49	11	2	0	3	0	0	0	1	0	1	0	0	0
8	Journal of Civil Engineering and Management	38	11	4	1	3	0	0	0	2	1	1	1	0	4
9	International Journal of Project Management	121	9	2	0	2	0	0	0	2	0	2	0	0	1
10	Cost Engineering Morgantown West Virginia	19	5	1	0	0	0	0	0	1	0	0	0	0	2
11	Journal of Computing in Civil Engineering	64	5	0	0	1	0	0	0	0	0	0	0	0	1
12	International Journal of Construction Management	14	5	2	0	2	2	2	1	1	0	2	0	0	1
13	Building and Environment	124	4	0	0	0	0	0	0	0	0	0	0	0	1
14	Jooumal of Financial Management of Property and Construction	17	4	1	0	0	0	0	0	1	0	0	0	0	0
15	EMJ Engineering Management Journal	32	3	1	0	0	0	0	0	0	0	0	0	0	0
16	Journal of Asian Architecture and Building Engineering	16	3	2	0	2	0	0	0	0	0	0	0	0	0
17	International Journal of Civil Engineering and Technology	18	2	0	0	0	0	0	0	0	0	0	0	0	0
18	Construction Innovation	32	2	0	0	0	0	0	0	1	0	0	0	0	0
19	Computer Aided Civil and Infrastructure Engineering	68	2	1	0	2	0	0	0	0	0	0	0	0	1
20	Transportation Research Record	94	2	0	0	0	0	0	0	0	0	0	0	0	0
21	Electronic Journal of Information Technology in Construction	38	2	1	0	0	0	0	0	0	0	0	0	0	0
22	Journal of Information Technology in Construction	38	1	1	0	1	0	1	0	1	0	0	1	0	0
23	Journal of Architectural Engineering	30	1	0	0	0	0	0	0	0	0	0	0	0	1
24	Journal of Performance of Constructed Facilities	41	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL			227	53	12	50	8	9	8	32	8	28	9	9	49
%				23,35%	5,29%	22,03%	3,52%	3,96%	3,52%	14,10%	3,52%	12,33%	3,96%	3,96%	21,59%
MEAN				2,30	0,52	2,17	0,35	0,39	0,35	1,39	0,35	1,22	0,39	0,39	2,04
STD.DEV.				2,98	1,21	2,84	0,76	0,77	0,87	2,06	0,88	2,48	0,87	1,84	3,77

Table 4.5. Number of shared descriptive variables analysis for 1984 – 2010 period.

				REPORTED VALUES (1984 - 2009)											
CODE	JOURNAL NAME	H INDEX	NUMBER OF ARTICLE	MEAN	MEDIAN	STD. DEV.	SKEWNESS	KURTOSIS	DIAGNOSTIC TESTS	FULL CORRELATION TABLE	NUMBER OF RAW VARIABLES	NUMBER OF TRANSFORMED VARIABLES	REPRODUCABLE	DATA AVAILABILITY STATEMENT	CODE
1	Journal of Construction Engineering and Management	95	27	4	0	3	0	0	0	1	1	3	0	0	3
2	Construction Management and Economics	81	15	4	2	4	2	2	2	2	1	2	0	0	2
3	Automation in Construction	95	8	1	1	1	0	0	0	0	0	0	0	0	3
4	Canadian Journal of Civil Engineering	53	5	3	0	3	1	1	1	0	0	1	0	0	0
5	Engineering, Construction and Architectural Management	49	5	0	0	1	0	0	0	0	0	0	0	0	0
6	International Journal of Project Management	121	5	1	0	0	0	0	0	1	0	0	0	0	0
7	Cost Engineering Morgantown West Virginia	19	5	1	0	0	0	0	0	1	0	0	0	0	2
8	Journal of Management in Engineering	55	4	1	0	1	0	0	0	1	0	2	0	0	0
9	Building and Environment	124	4	0	0	0	0	0	0	0	0	0	0	0	1
10	Journal of Computing in Civil Engineering	64	2	0	0	0	0	0	0	0	0	0	0	0	1
11	Joournal of Financial Management of Property and Construction	17	2	1	0	0	0	0	0	0	0	0	0	0	0
12	EMJ Engineering Management Journal	32	2	1	0	0	0	0	0	0	0	0	0	0	0
13	Transportation Research Record	94	2	0	0	0	0	0	0	0	0	0	0	0	0
14	KSCE Journal of Civil Engineering	26	1	0	0	0	0	0	0	0	0	0	0	0	0
15	Journal of Asian Architecture and Building Engineering	16	1	1	0	1	0	0	0	0	0	0	0	0	0
16	Construction Innovation	32	1	0	0	0	0	0	0	0	0	0	0	0	0
17	Computer Aided Civil and Infrastructure Engineering	68	1	1	0	1	0	0	0	0	0	0	0	0	0
18	Electronic Journal of Information Technology in Construction	38	1	0	0	0	0	0	0	0	0	0	0	0	0
19	Journal of Architectural Engineering	30	1	0	0	0	0	0	0	0	0	0	0	0	1
20	Journal of Civil Engineering and Management	38	0	0	0	0	0	0	0	0	0	0	0	0	0
21	International Journal of Construction Management	14	0	0	0	0	0	0	0	0	0	0	0	0	0
22	International Journal of Civil Engineering and Technology	18	0	0	0	0	0	0	0	0	0	0	0	0	0
23	Journal of Information Technology in Construction	38	0	0	0	0	0	0	0	0	0	0	0	0	0
24	Journal of Performance of Constructed Facilities	41	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL			92	19	3	15	3	3	3	6	2	8	0	0	13
%				20,65%	3,26%	16,30%	3,26%	3,26%	3,26%	6,52%	2,17%	8,70%	0,00%	0,00%	14,13%
MEAN				1,00	0,16	0,79	0,16	0,16	0,16	0,32	0,11	0,42	0,00	0,00	0,54
STD.DEV.				1,26	0,49	1,20	0,49	0,49	0,49	0,57	0,31	0,88	0,00	0,00	0,96

Table 4.6. Number of shared descriptive variables analysis for 2010 – 2019 period.

				REPORTED VALUES (2010 - 2019)										
CODE	JOURNAL NAME	H INDEX	NUMBER OF ARTICLE	MEAN	MEDIAN	STD. DEV.	SKEWNESS	KURTOSIS	DIAGNOSTIC TESTS	FULL CORRELATION TABLE	NUMBER OF RAW VARIABLES	NUMBER OF TRANSFORMED VARIABLES	REPRODUCABLE	DATA AVAILABILITY STATEMENT	CODE
1	Journal of Construction Engineering and Management	95	35	7	3	7	1	1	4	4	2	7	3	9	11
2	Construction Management and Economics	81	14	6	3	6	1	1	1	5	2	5	3	0	1
3	Automation in Construction	95	15	1	0	3	0	0	0	1	0	0	0	0	11
4	KSCE Journal of Civil Engineering	26	13	3	0	1	0	0	0	2	1	0	0	0	3
5	Journal of Civil Engineering and Management	38	11	4	1	3	0	0	0	2	1	1	1	0	4
6	Journal of Management in Engineering	55	10	3	2	4	1	1	0	2	0	2	1	0	2
7	Canadian Journal of Civil Engineering	53	8	1	0	1	0	0	0	1	0	0	0	0	1
8	Engineering, Construction and Architectural Management	49	6	2	0	2	0	0	0	1	0	1	0	0	0
9	International Journal of Construction Management	14	5	2	0	2	2	2	1	1	0	2	0	0	1
10	International Journal of Project Management	121	4	1	0	2	0	0	0	1	0	2	0	0	1
11	Journal of Computing in Civil Engineering	64	3	0	0	1	0	0	0	0	0	0	0	0	0
12	Joournal of Financial Management of Property and Construction	17	2	0	0	0	0	0	0	0	0	0	0	0	0
13	Journal of Asian Architecture and Building Engineering	16	2	1	0	1	0	0	0	0	0	0	0	0	0
14	International Journal of Civil Engineering and Technology	18	2	0	0	0	0	0	0	0	0	0	0	0	0
15	EMJ Engineering Management Journal	32	1	0	0	0	0	0	0	0	0	0	0	0	0
16	Construction Innovation	32	1	0	0	0	0	0	0	1	0	0	0	0	0
17	Computer Aided Civil and Infrastructure Engineering	68	1	0	0	1	0	0	0	0	0	0	0	0	1
18	Electronic Journal of Information Technology in Construction	38	1	1	0	0	0	0	0	0	0	0	0	0	0
19	Journal of Information Technology in Construction	38	1	1	0	1	0	1	0	1	0	0	1	0	0
20	Cost Engineering Morgantown West Virginia	19	0	0	0	0	0	0	0	0	0	0	0	0	0
21	Building and Environment	124	0	0	0	0	0	0	0	0	0	0	0	0	0
22	Transportation Research Record	94	0	0	0	0	0	0	0	0	0	0	0	0	0
23	Journal of Architectural Engineering	30	0	0	0	0	0	0	0	0	0	0	0	0	0
24	Journal of Performance of Constructed Facilities	41	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL			135	33	9	35	5	6	6	22	6	20	9	9	36
%				24,44%	6,67%	25,93%	3,70%	4,44%	4,44%	16,30%	4,44%	14,81%	6,67%	6,67%	26,67%
MEAN				1,74	0,47	1,84	0,26	0,32	0,32	1,16	0,32	1,05	0,47	0,47	1,5
STD.DEV.				2,00	0,99	1,95	0,55	0,57	0,92	1,35	0,65	1,88	0,94	2,01	3,04

The aim of this thesis is to investigate how the concept of reproducibility is used in cost estimation method studies. Therefore, some criteria were examined in selected articles. The data we need to reproduce research is descriptive data (mean, median, standard deviation, min. And max.), sample size, and the most important full correlation table. In order to see how much of the cost estimation method is reproducible, the articles were also examined by looking at these criteria. At the end of the examination, it was seen that only one article could be reproduced.

Reproducibility is related to data sharing. Therefore, even if it cannot be reproduced, the question of how much data is shared in articles comes to mind. For finding answers to this question, shared data was reviewed and listed. The data sought in the articles are mean value, median value, standard deviation, sample size, diagnostic tests, skewness and kurtosis value, full correlation table, raw data variables, transformed data variables, code, and data statement availability.

CHAPTER 5

RESEARCH FINDINGS AND DISCUSSIONS

Descriptive variables were identified to help to examine the 227 selected articles for reproducibility. Key variables were determined as sample size, mean value, standard deviation and full corelation tables. Supporter variables were determined all descriptive variables, raw data and transformed data, diagnostic tests, code/pseudocode, skewness and kurtosis values. The following tables show that the mean and standard deviation values of these determination variables and show that the article rates.

Table 5.1. Findings and descriptive statistics for period 1984-2019.

REPORTED DESCRIPTIVE VARIABLES	Number of Articles N=227 (1984 - 2019) (% of sample)	Mean	Standard Dev.
		Statistic	Statistic
MEAN	53 (23,35%)	2.30	2.98
MEDIAN	12 (5,29%)	0.52	1.21
STANDARD DEVIATION	50 (22,05%)	2.17	2.84
SKEWNESS	8 (3,52%)	0.35	0.76
KURTOSIS	9 (3,96%)	0.39	0.77
DIAGNOSTIC TESTS	9 (3,96%)	0.35	0.87
CORRELATION TABLE (full or partial)	32 (14,10%)	1.39	2.06
RAW VARIABLES	8 (3,52%)	0.35	0.88
TRANSFORMED VARIABLES	28 (12,33%)	1.22	2.48
DATA AVAILABILITY STATEMENT	9 (3,96%)	0.39	1.84
REPRODUCABLE	9 (3,96%)	0.39	0.87
CODE	49 (21,59%)	2.04	3.77

Table 7 shows the descriptive variables mean, median, standard deviation, skewness, kurtosis, diagnostic tests, correlation tables, raw variables, transformed variables, and data availability statement variables. As well as mean and standard deviation values of the reported variables are shown.

Since the articles are divided and compared to two different periods, the reported values of the variables determined in the articles published from 1984 to 2009 in table 5.2. and the descriptive statistics of these variables are shown. Table 5.3. shows the data from 2010 to 2019. When the tables analyzed, it was seen how data sharing changes in two time periods.

Table 5.2. Findings and descriptive statistics for period 1984-2009.

REPORTED DESCRIPTIVE VARIABLES	Number of Articles N=92 (1984 - 2009) (% of sample)	Mean	Standard Dev.
		Statistic	Statistic
MEAN	19 (20,65%)	0.79	1.19
MEDIAN	3 (3,26%)	0.13	0.44
STANDARD DEVIATION	15 (16,30%)	0.63	1.11
SKEWNESS	3 (3,26%)	0.13	0.44
KURTOSIS	3 (3,26%)	0.13	0.44
DIAGNOSTIC TESTS	3 (3,26%)	0.13	0.44
CORRELATION TABLE (full or partial)	6 (6,52%)	0.25	0.52
RAW VARIABLES	2 (2,17%)	0.08	0.28
TRANSFORMED VARIABLES	8 (8,70%)	0.33	0.80
DATA AVAILABILITY STATEMENT	0 (0,00%)	0.00	0.00
REPRODUCABLE	0 (0,00%)	0.00	0.00
CODE	13 (14,13%)	0.54	0.96

Table 5.3. Findings and descriptive statistics for period 1984-2009.

REPORTED DESCRIPTIVE VARIABLES	Number of Articles N=135 (2010 - 2019) (% of sample)	Mean	Standard Dev.
		Statistic	Statistic
MEAN	33 (24,44%)	1.38	1.91
MEDIAN	9 (6,67%)	0.38	0.90
STANDARD DEVIATION	35 (25,93%)	1.46	1.89
SKEWNESS	5 (3,70%)	0.21	0.50
KURTOSIS	6 (4,44%)	0.25	0.52
DIAGNOSTIC TESTS	6 (4,44%)	0.25	0.83
CORRELATION TABLE (full or partial)	22 (16,30%)	0.92	1.29
RAW VARIABLES	6 (4,44%)	0.25	0.60
TRANSFORMED VARIABLES	20 (14,81%)	0.83	1.72
DATA AVAILABILITY STATEMENT	9 (6,67%)	0.38	0.86
REPRODUCABLE	9 (6,67%)	0.38	1.80
CODE	36 (26,67%)	1.50	3.04

When examines the tables, the most reported data in the two periods are mean, standard deviation variables. The mean value of the empirical studies (N = 92) shared during the 1984-2009 period reportes in 19 of 20.65 percent and a standard deviation value of 15.30 percent. Between 2010 and 2019, the average value of 24.44 percent in 33 of the studies (N = 135) and standard deviation values in 25.93 percent of 35 were stated. An important factor in empirical studies published during the 2010-2019 period is the increase in the sharing of the correlation table and the data of transformed variables. There is an increase of 9.78 percent in the reporting of the correlation table data and 6.11 percent in the sharing of the transformed variable data. There is seen a maximum increase of 1.18 percent in the reporting of skewness, kurtosis, and diagnostic tests. The shared raw data findings increase from 2.17 percent to 4.44 percent. When examines the sharing of data availability statements, there is zero sharing during the period of 1984-2009 and this reportes as 6.67 percent in the 2010-2019 period. In this period (2010-2019), an increase in data sharing is expected. However, this increase is not at the expected level. When examines the sample sizes, it is seen that the ratio of the reported variable data is very small. For this reason, the number of reproduced studies is very few. The reproducibility of a study is directly proportional to the shared research data information.

This value proves how low the share of study data is. In order for a study to be reproduced, the researcher must have all the data in full, which codes are used in the software and analysis, which code is run at which stage, and the sequence in which the analyzes are applied. The rate of sharing such data in the articles reviewed is very low. For this reason, the number of reproduced studies is so small. The reproducibility of a study is directly proportional to the shared research data information.

As data sharing has became more of an issue in recent years, publishers and magazines have become interested in this issue closely. International organizations publish an various notices and an international standard was established for data sharing. Publishers and journals set up their own data sharing policies and adopted the proper implementation of these policies. According to this policy, if the authors want the articles to be published in these journals, they have to add “data availability statements” to their studies. This section shows how and where we can access research data. While analysing the variables identified in the articles, it is also examined whether or not this section exists. Only 9 of them were found to be within the 227 articles of this chapter. This is only seen in articles published in the 'Journal of Construction Engineering and Management'.

In this study, 227 articles about cost estimation methods are examined. Most of the cost estimation methods mentione in Chapter 3 are the estimation methods of these articles. After reviewing 227 articles, it is found that it is impossible to reproduce 218 out of them and the reasons for the inability to repeat the studies were identified.

After the articles examine and the necessary data is reported, it is evaluated whether the results of the articles could be reproduced. As a result of this evaluation, the causes of the non-reproducible results are determined (the full list of causes is shown in the table.). The reasons why research results cannot be reproduced are:

• Descriptive statistics not reported

• Lost data in key variable

• No sample size reported

• Raw data and raw data descriptor statistics not shared

• Variables shared with modified values

• Correlation matrices tables not fully reported

• No diagnostic tests reported

• Cost calculation method not specified

The percentages shared in Table 5.4. are the ratio of the reported data to the total sample size. The percentages given in Table 5.5. are the ratio of the total number of data reported to the number of articles shared in the period under review.

Table 5.4. Results of reproducibility study findings for N=227.

	Number of Articles (% of sample) N=227	
Reason results could not reproduced	(1984 - 2009) N= 92	(2010 - 2019) N=135
Descriptive statistics not reported	55 (24,33%)	58 (25,55%)
Descriptive statistics missing for key variables	58 (25,55%)	67 (29,52%)
Sample size not reported in results	7 (3,08%)	6 (2,64%)
Descriptive statistics not given for raw variables	90 (39,65%)	129 (56,83%)
Transformed variables reported	8 (3,52%)	20 (8,81%)
Not reported table of correlations matrix	86 (37,89%)	113 (49,78%)
Descriptive statistics given for full sample	3 (1,32%)	8 (3,52%)
Total articles for which reproducibility analysis was not possible	92 (40,53%)	126 (55,51%)
Diagnostic tests not reported	89 (39,21%)	129 (56,83%)

Table 5.5. Results of reproducibility study findings for N=92 and N=135.

	Number of Articles (% of sample) N=227	
Reason results could not reproduced	(1984 - 2009) N= 92	(2010 - 2019) N=135
Descriptive statistics not reported	55 (59,78%)	58 (42,96%)
Descriptive statistics missing for key variables	58 (63,04%)	67 (49,63%)
Sample size not reported in results	7 (7,61%)	6 (4,44%)
Descriptive statistics not given for raw variables	90 (97,83%)	129 (95,56%)
Transformed variables reported	8 (8,70%)	20 (14,81%)
Not reported table of correlations matrix	86 (93,48%)	113 (83,70%)
Descriptive statistics given for full sample	3 (3,26%)	8 (5,93%)
Total articles for which reproducibility analysis was not possible	92 (100,00%)	126 (93,33%)
Diagnostic tests not reported	89 (96,74%)	129 (95,56%)

The required data for the cost estimation method research to be reproduced is descriptive data, which is sufficient to reproduce only the mean and standard deviation value, the sample size, and most importantly the full correlation table. When examining the articles, it is examined whether these variables are shared or not. Of the 227 articles, 218 (96.04%) could not be reproduced because of insufficient data. Of these, 112 (49.34%) of them do not allow reproduction because the descriptive data (mean, median, SD, minimum, maximum) were not shared. In this 112 article, no descriptive data was shared. In 124 (54.63%) of the articles, descriptive data was shared incomplete. It does not allow the reproduction of the studies because one or both of the mean and standard deviation values required for reproduction are not specified. The number of studies where all descriptive data is shared is 12 (5,29%).

In total, 218 (96.04%) of the 227 cost estimation method surveys did not report sufficient information to allow for any repeatability analysis. In the period from 1984 to 2009, 92 of the articles that were shared did not meet the criteria for repeatability analysis. Between 2010-2019, 126 (93.33%) shares could not be reproduced. 55 (63,04%) of the articles shared between 1984 and 2009 were not reported descriptive statistics (mean, median, SD), 58 (63,04%) had missing data in the key variables, 7 (7, 61%) could not be reproduced because the sample size was not defined. In 90 (97.83%) of them, raw data and descriptive statistics of these data were reported, and in 8 (8.70%) only the sharing of transformed variables prevented reproduction. In 86 (93.48%) of the articles, no full or partial correlation matrix was reported, since the most important data of reproducibility are correlation values, it is not possible to repeat the results. When examine at the results of the analysis, the two most important reasons why the results of the articles published in this period cannot be repeated are that raw data and exact correlation matrices are not reported.

Since 58 (42.96%) of the articles shared between 2010-2019 were not reported descriptive statistics, 67 (49.63%) were missing data in the key variables, 6 (4.44%) sample size the results could not be reproduced because they were not reported. 129 (95.56) of the articles prevented reproduction because raw data and descriptive statistics of raw data were not reported and 20 (14.81%) used transformed variables in regressions. The results could not be reproduced because 113 (83.70%) articles did not share the full correlation table. The two main reasons for the failure to reproduce shared articles during this period are the same as for the other period. However, Table 5.5 is shown that the rate of non-sharing of raw data in the period of 1984-2009 was 97.83, while the ratio between 2010-2019 was 95.56. Although not a significant improvement, there is still an improvement. When examines the correlation tables between 1984 and 2009, 93.48 percent of the data were not reported, while the 2010-2019 ratio of unreported correlation matrix rate is 83.70 percent. There has been a 10 percent difference between the two periods, which may indicate that data sharing has increased in recent years.

Without knowing the sample size of a research, we cannot reproduce it correctly. Only nine articles do not show sample size information. One of these nine articles cannot be reproduced as no examples are specified.. The reason that other studies could not be reproduced is the lack of other variables.

The raw data for a study is important because it allows to reproduce the study using the original data. One of the reasons why a total of 219 (96,48) studies could not be reproduced is the lack of raw data information. In almost all of the articles, this information has not been disclosed to the reader, 219 articles are high.

As seen in most researches, when entering data into analyzes, the transformed data is entered and used instead of raw data. In articles, authors often share this transformed data rather than raw data. But if we want to reproduce a study, the primary data we need is raw data. The transformed or analyzed data are not be functional. In 28 (12,33%) of the articles reviewed, the transformed version of descriptive statistics was shared but could not be reproduced due to the need for their raw form in the analyzes.

The most necessary variable to reproduce a study is the full correlation matrix. 195 (85,90%) article does not contain correlations table data. Partial table is shared in 2 articles (0.88%). Since there was no full correlation table, 197 (86.78%) could not be analyzed. In the studies where the partial table is shared, the missing data can be found by different analysis and simulation techniques, but it is not reproduced partially because the estimation of the data reached and the accuracy of the estimation method used may not give accurate information.

Diagnostic tests, skewness and kurtosis values are variables that help us to compare cost estimation methods in-house and other research results. These values allow us to understand whether the data shows normal distribution. Diagnostic test data are not disclosed in 219 (96.48%) articles.

Only nine out of all studies provides sufficient descriptive summary data to allow reproduction. One of them shared all the data and software results of the study, the data snd the table to be retrieved when the study is recreated. Therefore, this article did not need to be re-analyzed. One of the studies could not be reproduced completely because they did not share the values of two variables in the correlation table. Although two of the nine studies shared the full correlation table, the data could not be analyzed due to lack of clarity. As a result, the number of studies that can be reproduced in 227 articles was determined to be five (2.20%).

Eight of the 24 journals were selected to compare the empirical results shared during the periods 1984-2009 and 2010-2019 in more detail.These 8 journals share the most articles on cost estimation methods in the period 1984-2019. The first 3 of these articles are in the top 3 in both periods. These magazines are; 'Journal of Construction Engineering and Management', 'Construction Management and Economics',' Automation in Construction ',' KSCE Journal of Civil Engineering ',' Journal of Civil Engineering and Management ',' Journal of Management in Engineering ',' Canadian Journal of Civil Engineering 'and' Engineering, Construction and Architectural Management '. Since the sample size in other journals is very small, the remaining 16 journals are not examined in this section. In this comparison, firstly, 11 variables were analyzed according to the changes in the journals. Later, the changes in the journals were examined.

Table 5.6. Number of shared descriptive variables analysis for 1984 - 2010 period for eight selected journal.

				1984 - 2009											
Journal Code	Journal Name	H Index	Number of Article	Mean	Median	Std. Dev.	Skewness	Kurtosis	Diagnostic Tests	Full Correlation Table	Number of Raw Variables	Number of Transformed Variables	Reproducable	Data Availability Statement	Code
1	Journal of Construction Engineering and Management	95	27	4	0	3	0	0	0	1	1	3	0	0	3
2	Construction Management and Economics	81	15	4	2	4	2	2	2	2	1	2	0	0	2
3	Automation in Construction	95	8	1	1	1	0	0	0	0	0	0	0	0	3
4	KSCE Journal of Civil Engineering	26	1	0	0	0	0	0	0	0	0	0	0	0	0
5	Journal of Civil Engineering and Management	38	0	0	0	0	0	0	0	0	0	0	0	0	0
6	Journal of Management in Engineering	55	4	1	0	1	0	0	0	1	0	2	0	0	0
7	Canadian Journal of Civil Engineering	53	5	3	0	3	1	1	1	0	0	1	0	0	0
8	Engineering, Construction and Architectural Management	49	5	0	0	1	0	0	0	0	0	0	0	0	0
TOTAL			65	13	3	13	3	3	3	4	2	8	0	0	8

Table 5.7. Ratio to the number of articles in the journal per journal.

				1984 - 2009											
Code	Journal Name	H Index	Number of Article	Mean	Median	Std. Dev.	Skewness	Kurtosis	Diagnostic Tests	Full Correlation Table	Number of Raw Variables	Number of Transformed Variables	Reproducable	Data Availability Statement	Code
1	Journal of Construction Engineering and Management	95	27	6,15%	0,00%	4,62%	0,00%	0,00%	0,00%	1,54%	1,54%	4,62%	0,00%	0,00%	4,62%
2	Construction Management and Economics	81	15	6,15%	3,08%	6,15%	3,08%	3,08%	3,08%	3,08%	1,54%	3,08%	0,00%	0,00%	3,08%
3	Automation in Construction	95	8	1,54%	1,54%	1,54%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	4,62%
4	KSCE Journal of Civil Engineering	26	1	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
5	Journal of Civil Engineering and Management	38	0	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
6	Journal of Management in Engineering	55	4	1,54%	0,00%	1,54%	0,00%	0,00%	0,00%	1,54%	0,00%	3,08%	0,00%	0,00%	0,00%
7	Canadian Journal of Civil Engineering	53	5	4,62%	0,00%	4,62%	1,54%	1,54%	1,54%	0,00%	0,00%	1,54%	0,00%	0,00%	0,00%
8	Engineering, Construction and Architectural Management	49	5	0,00%	0,00%	1,54%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
TOTAL			65	20,00%	4,62%	20,00%	4,62%	4,62%	4,62%	6,15%	3,08%	12,31%	0,00%	0,00%	12,31%

Table 5.8. Number of shared descriptive variables analysis for 2010 - 2019 period for eight selected journal (N=227)

				2010 - 2019											
Journal Code	Journal Name	H Index	Number of Article	Mean	Median	Std. Dev.	Skewness	Kurtosis	Diagnostic Tests	Full Correlation Table	Number of Raw Variables	Number of Transformed Variables	Reproducable	Data Availability Statement	Code
1	Journal of Construction Engineering and Management	95	35	7	3	7	1	1	4	4	2	7	3	9	11
2	Construction Management and Economics	81	14	6	3	6	1	1	1	5	2	5	3	0	1
3	Automation in Construction	95	15	1	0	3	0	0	0	1	0	0	0	0	11
4	KSCE Journal of Civil Engineering	26	13	3	0	1	0	0	0	2	1	0	0	0	3
5	Journal of Civil Engineering and Management	38	11	4	1	3	0	0	0	2	1	1	1	0	4
6	Journal of Management in Engineering	55	10	3	2	4	1	1	0	2	0	2	1	0	2
7	Canadian Journal of Civil Engineering	53	8	1	0	1	0	0	0	1	0	0	0	0	1
8	Engineering, Construction and Architectural Management	49	6	2	0	2	0	0	0	1	0	1	0	0	0
TOTAL			112	27	9	27	3	3	5	18	6	16	8	9	33

Table 5.9. The ratio to total number of articles.

				2010 - 2019											
Journal Code	Journal Name	H Index	Number of Article	Mean	Median	Std. Dev.	Skewness	Kurtosis	Diagnostic Tests	Full Correlation Table	Number of Raw Variables	Number of Transformed Variables	Reproducable	Data Availability Statement	Code
1	Journal of Construction Engineering and Management	95	35	6,25%	2,68%	6,25%	0,89%	0,89%	3,57%	3,57%	1,79%	6,25%	2,68%	8,04%	9,82%
2	Construction Management and Economics	81	14	5,36%	2,68%	5,36%	0,89%	0,89%	0,89%	4,46%	1,79%	4,46%	2,68%	0,00%	0,89%
3	Automation in Construction	95	15	0,89%	0,00%	2,68%	0,00%	0,00%	0,00%	0,89%	0,00%	0,00%	0,00%	0,00%	9,82%
4	KSCE Journal of Civil Engineering	26	13	2,68%	0,00%	0,89%	0,00%	0,00%	0,00%	1,79%	0,89%	0,00%	0,00%	0,00%	2,68%
5	Journal of Civil Engineering and Management	38	11	3,57%	0,89%	2,68%	0,00%	0,00%	0,00%	1,79%	0,89%	0,89%	0,89%	0,00%	3,57%
6	Journal of Management in Engineering	55	10	2,68%	1,79%	3,57%	0,89%	0,89%	0,00%	1,79%	0,00%	1,79%	0,89%	0,00%	1,79%
7	Canadian Journal of Civil Engineering	53	8	0,89%	0,00%	0,89%	0,00%	0,00%	0,00%	0,89%	0,00%	0,00%	0,00%	0,00%	0,89%
8	Engineering, Construction and Architectural Management	49	6	1,79%	0,00%	1,79%	0,00%	0,00%	0,00%	0,89%	0,00%	0,89%	0,00%	0,00%	0,00%
Total			112	24,11%	8,04%	24,11%	2,68%	2,68%	4,46%	16,07%	5,36%	14,29%	7,14%	8,04%	29,46%

5.1. Analysis of the Change Rate of Descriptive Statistics in Journals Over Time

While explaining the review, it will be explained not with the names of the journals but with the number codes given.

5.1.1. Mean Value

When examine the mean values reported in the first period of the first period of 6.15% from 6.15% in the second period, 6.25%, 6. journals increase from 1.54% to 2.68%. The rate in the second journal is 6.15% in the first period, to 5.36% in the second period, from 1.54% to 0.89% in the 3rd journal and from 0.82% to 4.69% in the 7th journal. In the journals 4,5 and 8, no mean data is shared during the period of 1984-2009, while data for the period 2010-2019 began to be shared. The rate in the 4th journal increases to 2,68%, in the 5th to 3.57% and in the 8th journal to 1.79. When examine the table, the most striking difference is that the rate increase in the 5th journal and the decrease of 3.73% instead of the expected increase in the 7th journal.

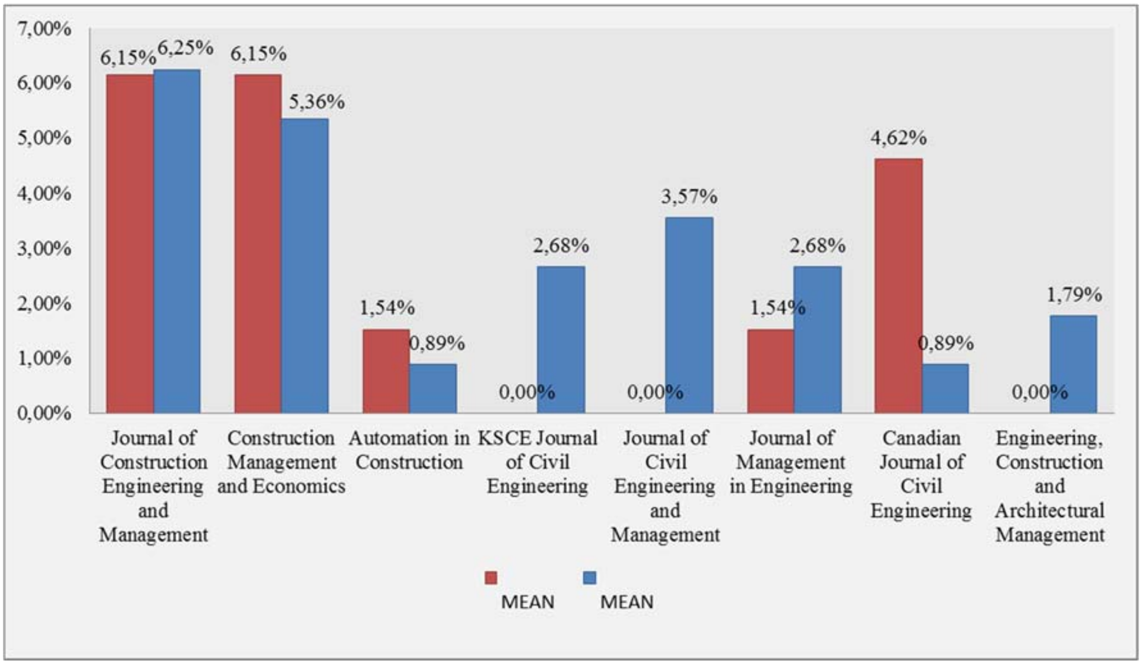

Figure 5.1. Rates of reported mean variable.

The total frequency of articles published during the period 1984-2009 and 2010-2019 increase from 20 percent to 24.11 percent. When look at the collection, there is an improvement, although not on a large scale. According to ANOVA test, $p < 0.05$ and the results were statistically significant.

5.1.2. Median Value

When looking at the reported median values, we see an increase in the share rate in journals 1.5 and 6. While there is no data reported in the 1st journal in the period of 1984-2009, the rate of data reported in 2010-2019 period is 2.68%. Similarly, it increased to 0.89% in the 5th journal and 1.79% in the 6th journal. 2. While the first period is 3.08% in the journal, it decreases to 2.68% in the period after, and the rate in the third journal decreased from 1.54% to 0. 4, 7. And 8. Median value was not reported in any of the articles published in journals in both periods. The graph shows that it can be see that the changes are very small differences.

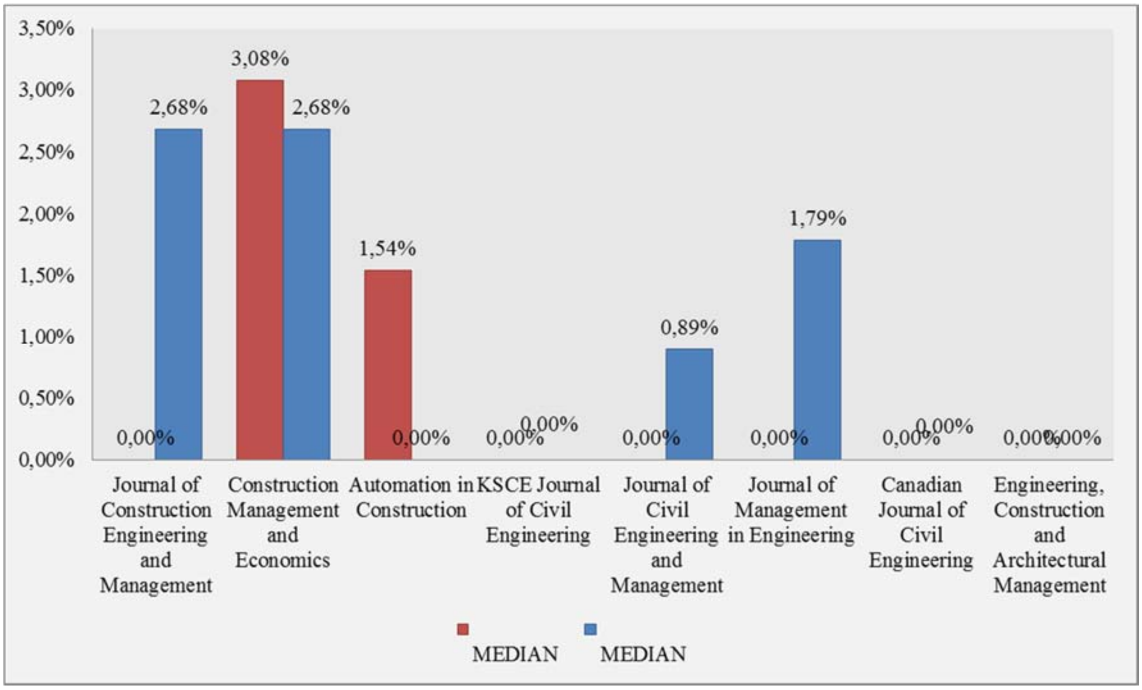

Figure 5.2. Rates of reported median variable.

The total frequency of articles published during the period 1984-2009 and 2010-2019 increased from 4.62 percent to 8.04 percent. When we look at the collection, there is an improvement, although not on a large scale. According to ANOVA test, $p < 0.05$ and the results were statistically significant.

5.1.3. Standart Deviation

When examines the standard deviation graph, it is seen that there is an increase in the reported standard deviation data during 2010-2019 period. The ratio in the 1st journal is from 4.62% to 6.25%, in the 3rd journal from 1.54% to 2.68%, in the 5th journal from 1.54% to 3.57 and in the 8th journal increases from 1.54% to 1.79%. The rate in the second journal decreased from 6.15% to 5.36 and in the 5th journal it decreases from 4.62% to 0.89%. In the 4th and 5th journals, there is no standard deviation data reported during the period of 1984-2009, while the ratio increased to 0.89% and 2,685 in the 2010-2019 period.

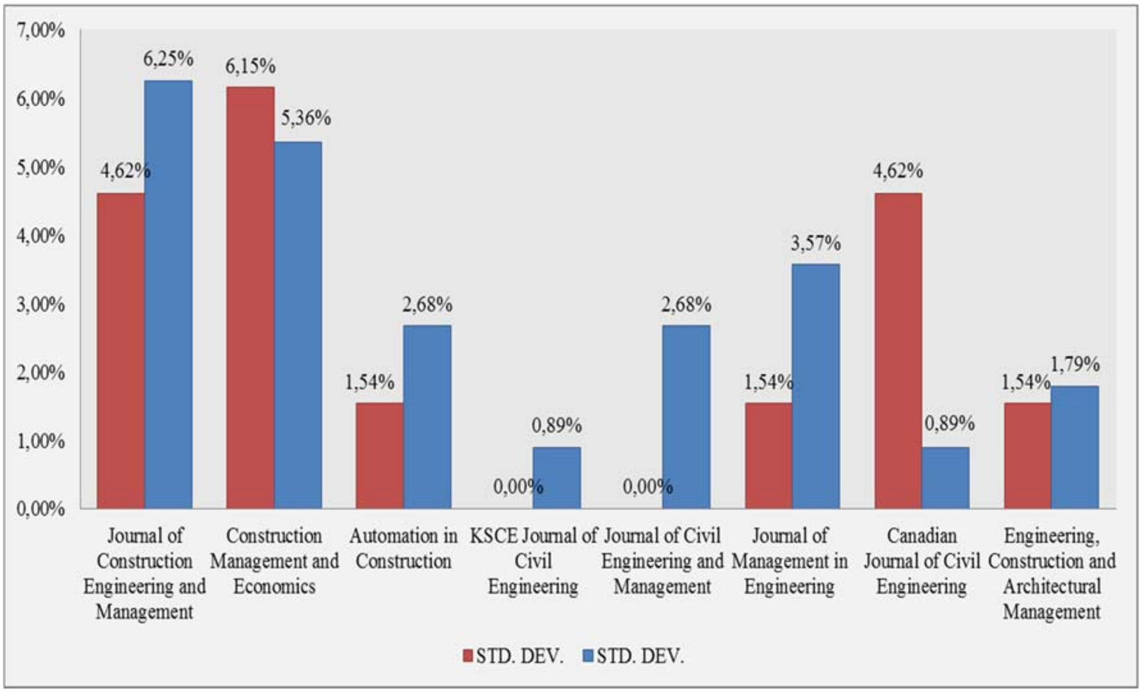

Figure 5.3. Rates of reported standart deviation variable.

The total frequency of articles published during the period 1984-2009 and 2010-2019 increased from 20 percent to 24.11 percent. The graph is shown that there is an improvement, although not on a large scale. According to ANOVA test, p <0.05 and the results were statistically significant.

5.1.4. Skewness

The skewness graph shows that the first thing that stands out is the low amount of data reported. In total, only eight skewness data are reported in the article. Looking at the graph, the reported data increased from 0% to 0.89 in the 1st journal and from 0% to 0.89% in the 6th journal. 2. It decreases from 3.08% to 0.89 in the journal and from 1.54 in the 7th journal to 0%. The remaining journals do not have any skewness data reported in any article for two periods.

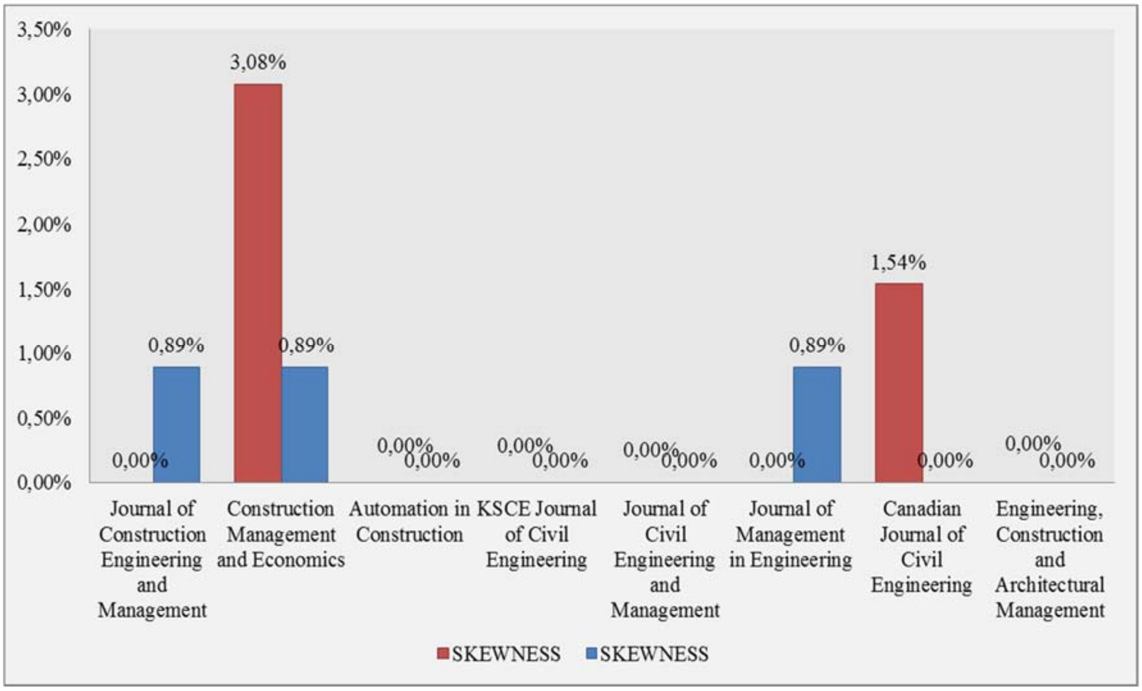

Figure 5.4. Rates of reported skewness variable.

The total frequency of articles published during the period 1984-2009 and 2010-2019 decreased from 4.62 percent to 2.68 percent. When we look at the collection, there is an improvement, although not on a large scale. According to ANOVA test, $p < 0.05$ and the results were statistically significant.

5.1.5. Kurtosis

The Kurtosis graph, it has the same values as the skewness graph. . Looking at the graph,the reported data increased from 0% to 0.89 in the 1st journal and from 0% to 0.89% in the 6th journal. 2. It decreased from 3.08% to 0.89 in the journal and from 1.54 in the 7th journal to 0%. In the remaining journals, there are no kurtosis data reported in any article for two periods.

The total frequency of articles published during the period 1984-2009 and 2010-2019 decreased from 4.62 percent to 2.68 percent. The graph illustrates that there is an improvement, although not on a large scale. According to ANOVA test, $p < 0.05$ and the results were statistically significant.

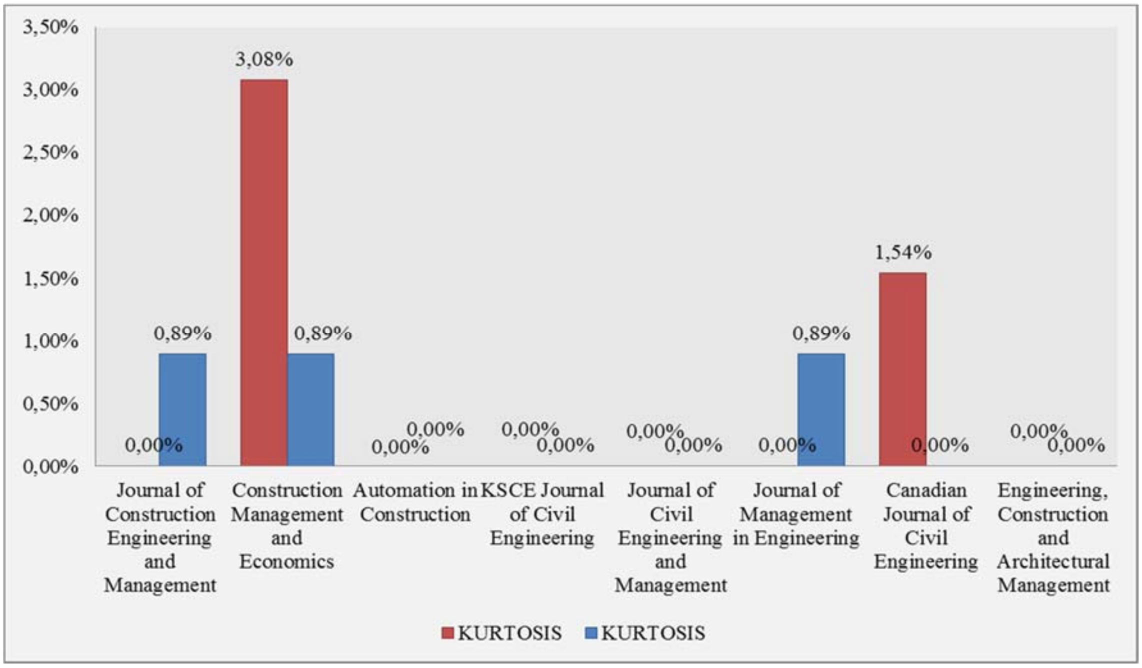

Figure 5.5. Rates of reported kurtosis variable.

5.1.6. Diagnostic Tests

When examines the graph of diagnostic tests, the data reported in the first journal increased from 0 percent to 3.57 percent. It decreases from 3.08% to 0.89% in the 2nd journal and from 0% to 1.54% in the 7th journal. The remaining journals do not have any shared diagnostic test findings in either period. The graph determines that the sharing rate of the variables is very low, and contrary to expectations, the rate of sharing the findings in the articles published during 2010-2019 period decreased rather than increasing.

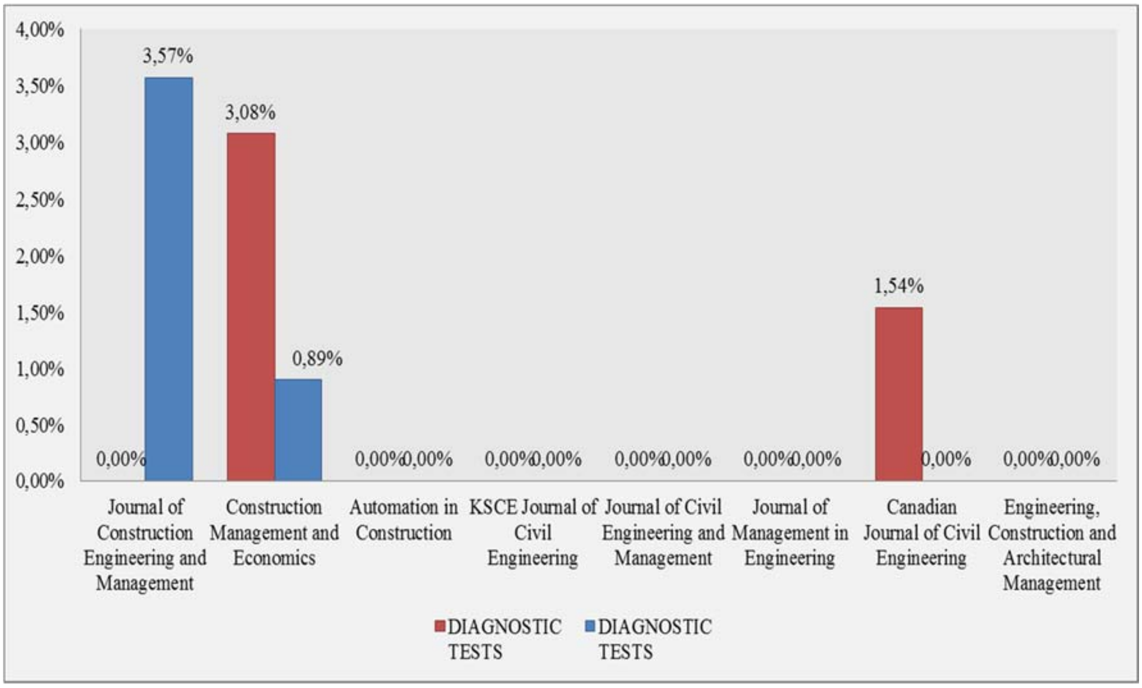

Figure 5.6. Rates of reported diagnostic test variable.

The total frequency of articles published during the period 1984-2009 and 2010-2019 decreased from 4.62 percent to 4.46 percent. The graph shows that there is an improvement, though not on a large scale.According to ANOVA test, p <0.05 and the results were statistically significant.

5.1.7. Correlation Table (Full and partial)

The correlation table graph shows that it is seen that the data sharing increase that we expect to see in the articles shared during 2010-2019 period. Correlation table data reported in articles published in all journals increase. Increases from 1.54% to 3.57% in the 1st journal, from 3.08% to 4.46% in the second journal and from 154% to 1.79% in the 6th journal. There are no data reported in the periodicals between 1984-2009. When looking at the period of 2010-2019, it is 0.89% in 3rd journal, 1.79% in 4th journal, 1.79% in 5th journal, 0.89% in 7th journal and %0 in 8th journal increased to 89%.

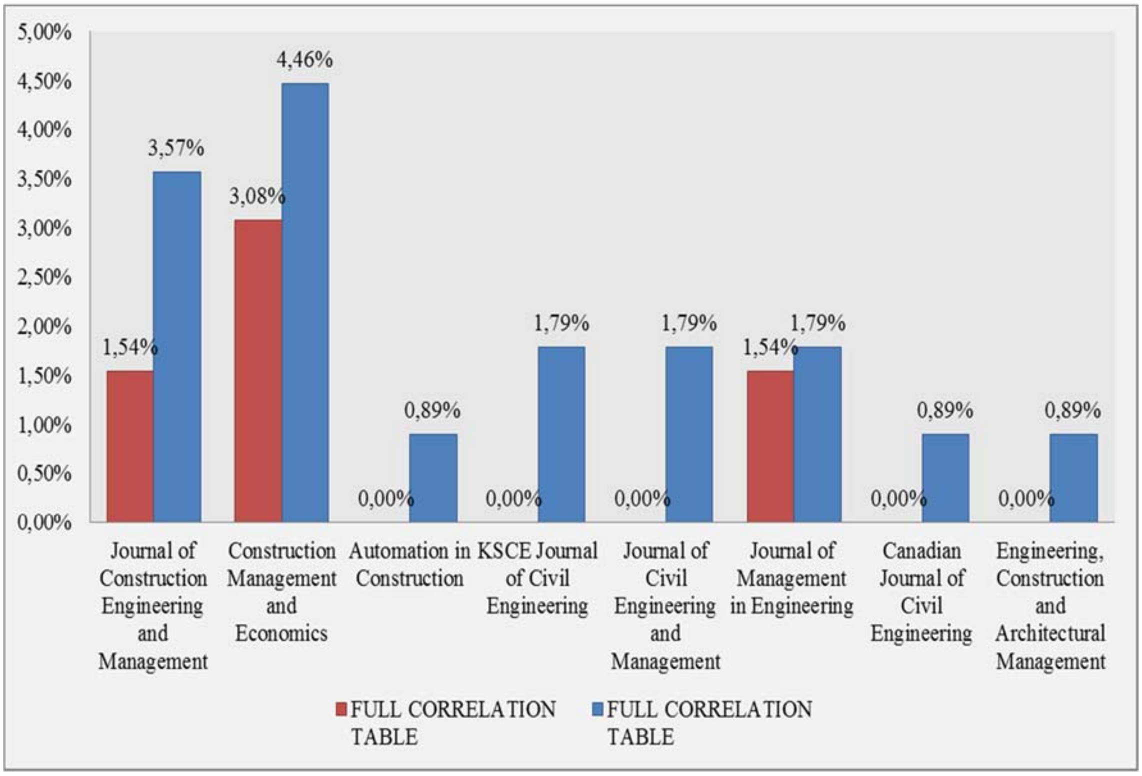

Figure 5.7. Rates of reported correlation table variable.

The total frequency of articles published during the period 1984-2009 and 2010-2019 decreased from 6.15 percent to 16.07 percent. The graph shows that there is an improvement, although not on a large scale. According to ANOVA test, p <0.05 and the results were statistically significant.

In addition, correlation data was shared in a total of 31 articles. 15 out of 31 articles were shared full correlation table and in the 16 articles shared partial correlation table.

5.1.8. Raw Variables

The graph shows that the raw data rate reported in the 1st magazine increased from 1.54% to 1.79% and in the second journal increased from 1.54% to 1.79%. It increased from 0 percent to 0.89 percent in the 4th and 5th journals. There are no findings reported in articles published in other journals during both periods. There is an increase in data sharing however still this increase does not reach the desired standard.

The total frequency of articles published during the period 1984-2009 and 2010-2019 increased from 3.08 percent to 5.36 percent. The graph shows that there is an improvement, although not on a large scale. According to ANOVA test, p <0.05 and the results were statistically significant.

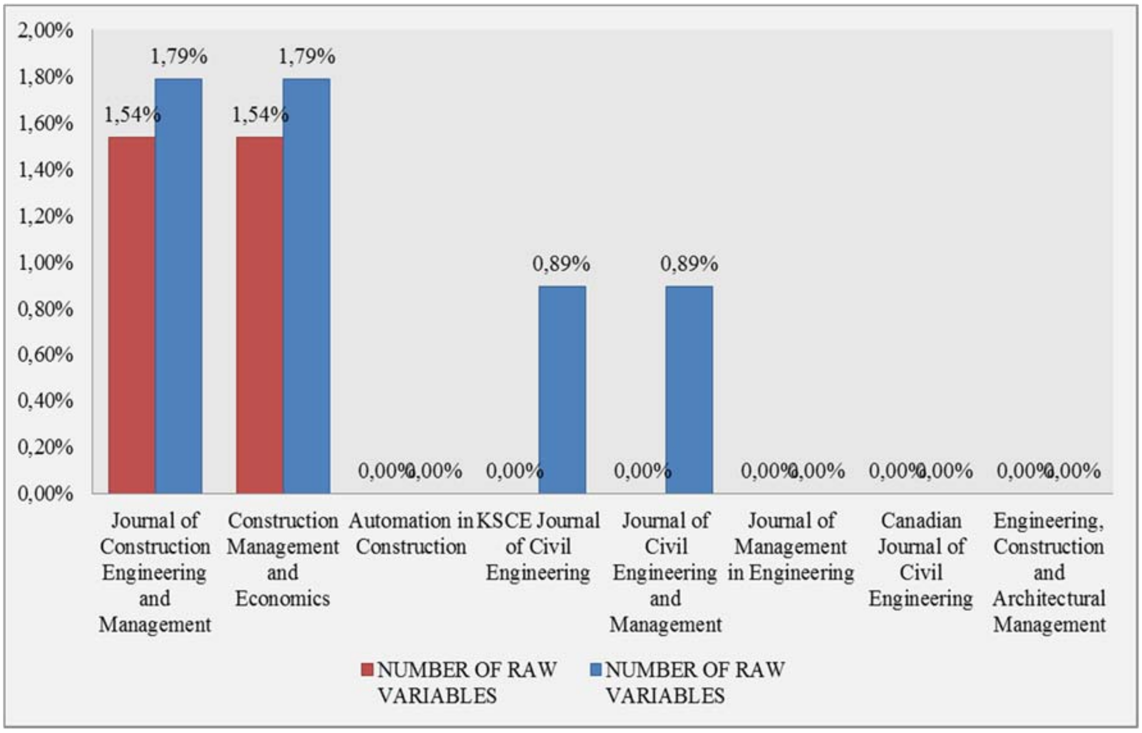

Figure 5.8. Rates of reported raw data variables.

5.1.9. Transformed Variables

When examines the graph, the number of transformed variables reported is from 4.62 percent to 6.25 in 1st magazine, from 3.08 percent to 4.26 percent in 2nd journal, and from 0 percent to 0 percent in 5th and 8th journals. 89. The rate in the 6th journal decreases from 3.08 percent to 1.79 percent and in the 7th journals the ratio decrease from 1.54 percent to 0 percent. There are no findings reported in the 3rd and 4th journals.

The total frequency of articles published during the period 1984-2009 and 2010-2019 increased from 12.31 percent to 14.29 percent. The graph shows that there is an improvement, although not on a large scale. According to ANOVA test, $p < 0.05$ and the results were statistically significant.

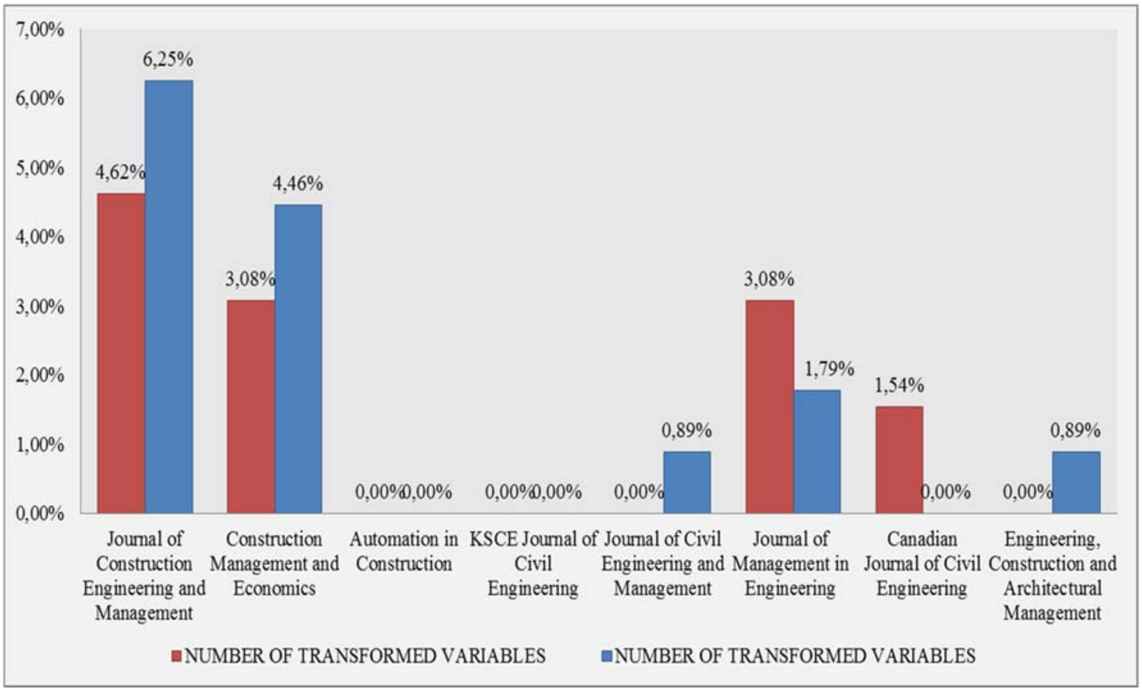

Figure 5.9. Rates of reported transported data variable.

5.1.10. Code

When examines the code/pseudocode graph, it is seen that there is an increase in the reported code data during 2010-2019 period. The ratio in the 1st journal is from

4.62% to 9,82%, in the 3rd journal from 4,62% to 9,82%, in the 4th journal from 0% to 2,68%, in the 5th journal increases from 0% to 3,57%, in the 6th journal from 0% to 1,79 and in the 7th journal from 0% to 0,89%. The rate in the second journal decreases from 3,08% to 0,89. In the 8th journal, there was no code data reported during the period of 1984-2009 and 2010-2019 period.

In addition, computer code was shared in a total of 49 articles. 3 out of 49 articles were shared direct code and in the remaining 46 articles, the pseudo code was shared.

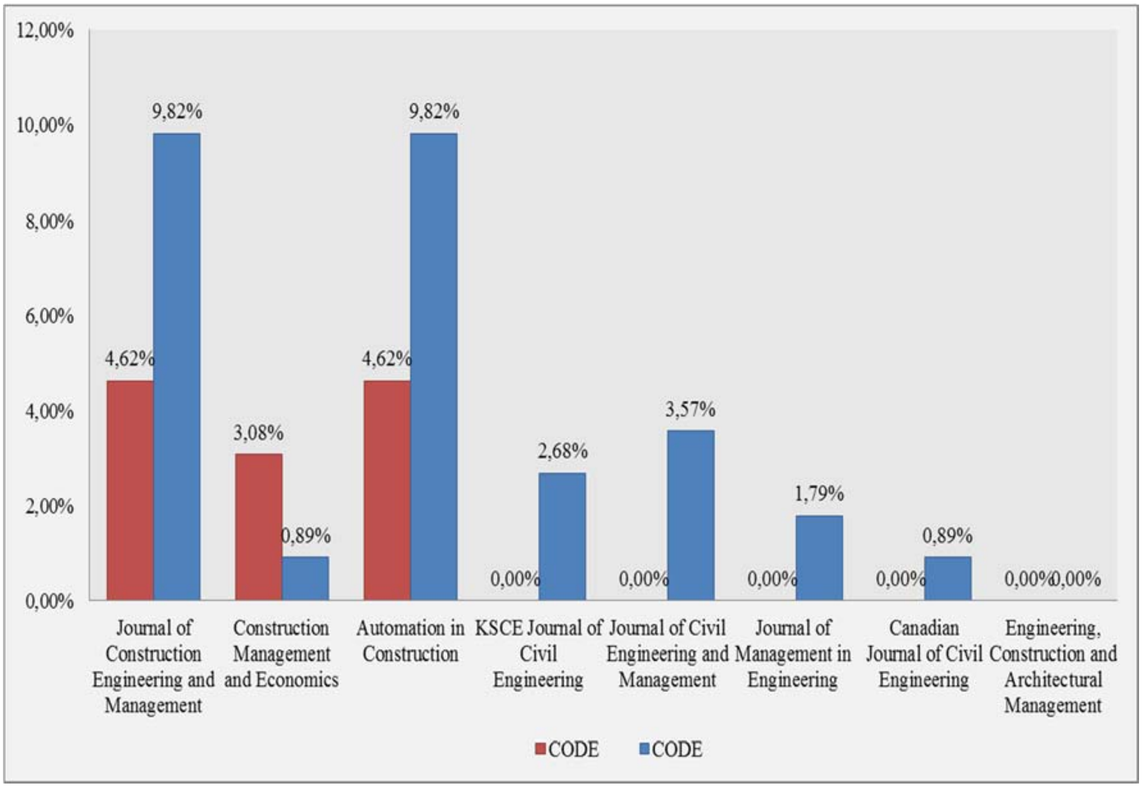

Figure 5.10. Rates of reported code variable.

5.1.11. Data Availability Statement

'Data availability statement 'section describes where and how we can access the study findings. In order to increase the reproduction of the study results, the data sharing graph shows that the number of articles that the data availability statement indicator is given is only 9. During the period 2010-2019, only the journal 1 was reported and the ratio increased from 0 percent to 8.04 percent.

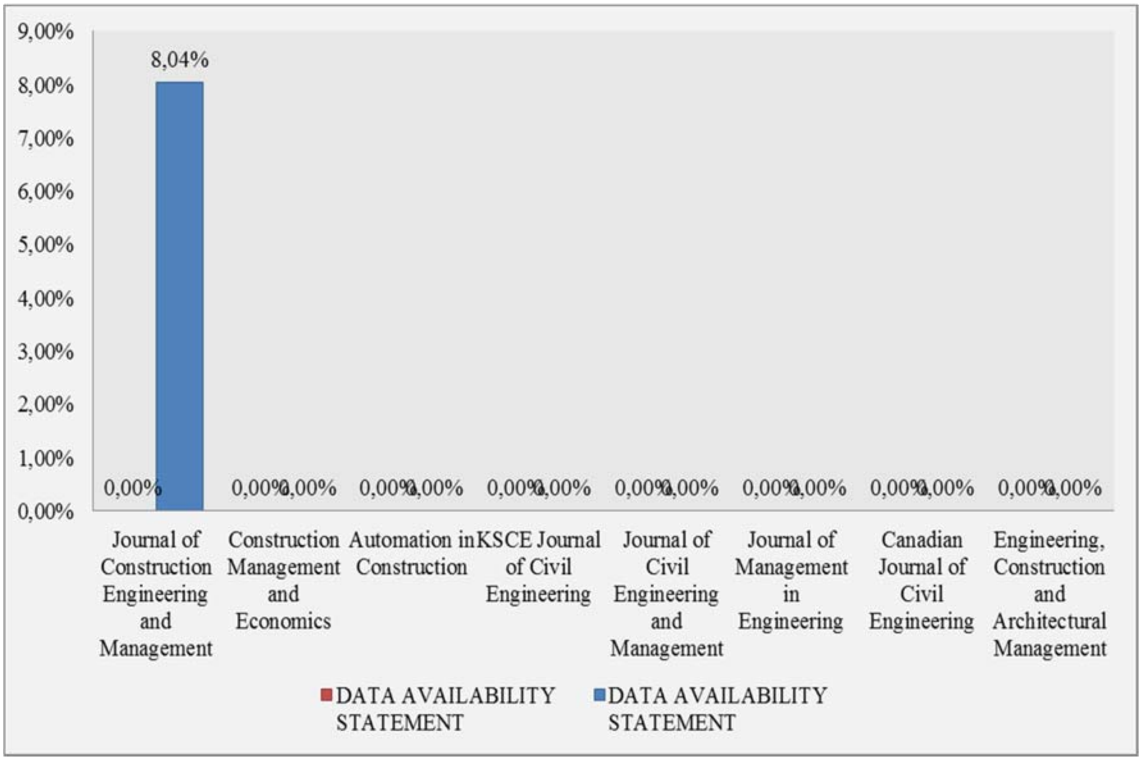

Figure 5.11. Rates of reported 'data availability statement' variable.

The total frequency of the articles published during the period 1984-2009 and 2010-2019 increased from 0 percent to 8.04 percent. The graph shows that there is an improvement, although not on a large scale. According to ANOVA test, $p < 0.05$ and the results were statistically significant.

The following table shows the publishers of the selected journals and whether they have a data availability statements policy. This policy was adopted in 20 out of 24 journals, and still not in the remaining four journals out of 24 journals. However, despite being adopted in 20 journals, it is still not mandatory. Therefore, the number of articles shared by this section is very low.

Table 5.10. Journal's "data availability statement policy" availabilities and the their publisher list.

CODE	JOURNAL NAME	PUBLISHER	DATA AVAILABILITY STATEMENT POLICY
1	Journal of Construction Engineering and Management	ASCE	+
2	Automation in Construction	Elsevier	+
3	Construction Management and Economics	Taylor and Francis	+
4	Cost Engineering Morgantown West Virginia	-	-
5	Canadian Journal of Civil Engineering	NRC Research Press	+
6	KSCE Journal of Civil Engineerig	co-published with Springer	+
7	Engineering, Construction and Architectural Management	Emerald	+
8	Journal of Computing in Civil Engineering	ASCE	+
9	International Journal of Project Management	Elsevier	+
10	Journal of Civil Engineering and Management	Taylor and Francis	+
11	Journal of Management in Engineering	ASCE	+
12	International Journal of Civil Engineering and Technology	IAEME Publication	-
13	International Journal of Construction Management	Taylor and Francis	+
14	Journal of Performance of Constructed Facilities	ASCE	+
15	Building and Environment	Elsevier	+
16	Construction Innovation	Emerald	+
17	Computer Aided Civil and Infrastructure Engineering	Wiley	+
18	Joournal of Financial Management of Property and Construction	Emerald	+
19	Journal of Information Technology in Construction	DOAJ	-
20	Transportation Research Record	SAGE	+
21	EMJ Engineering Management Journal	Taylor and Francis	+
22	Journal of Architectural Engineering	ASCE	+
23	Journal of Asian Architecture and Building Engineering	Taylor and Francis	+
24	Electronic Journal of Information Technology in Construction	-	

5.1.12. Reproducible

The graph shows the proportion of articles whose study findings can be reproduced. When we examine the graph, none of the studies published during the period of 1984-2009 could be reproduced. For articles published during the period 2010-2019, the rate increases to 2.68 percent in journals 1, 2.68 percent in journals 2, and 0.89 percent in journals 5 and 6. In the remaining journals, there are no articles that provide sufficient data to reproduce.

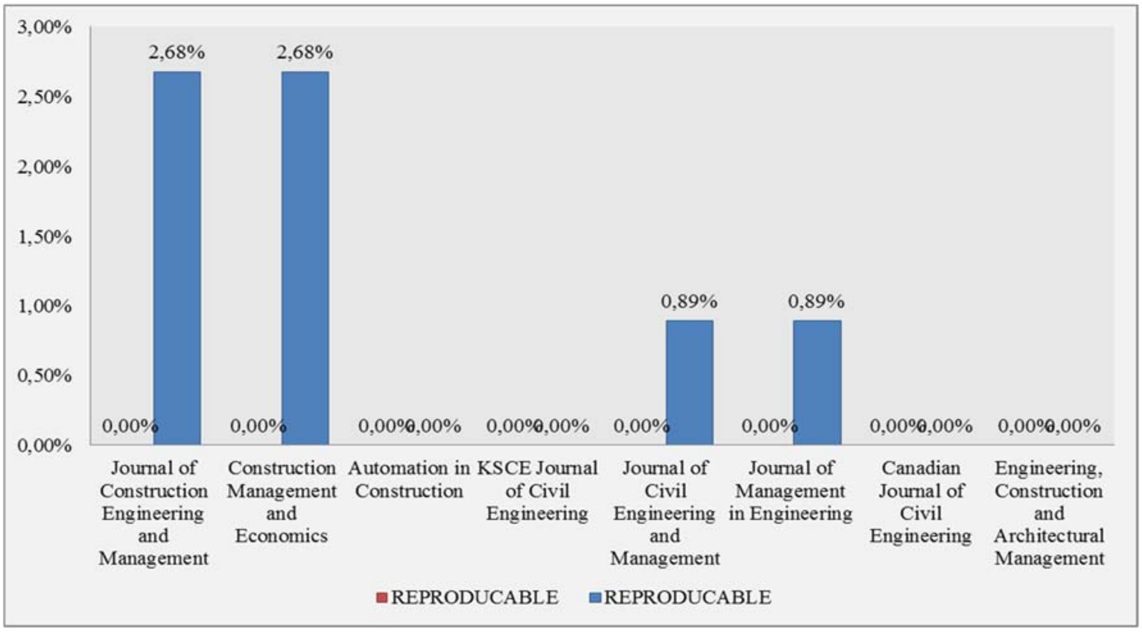

Figure 5.12. Rates of reported reproducable article data.

The total frequency of the articles published during the period 1984-2009 and 2010-2019 increased from 0 percent to 7.14 percent. The graph shows that there is an improvement, although not on a large scale. According to ANOVA test, $p < 0.05$ and the results were statistically significant.

After the all examinations, has shown only one article out of 227 articles can reproduce. This articles is *Rafiei, M.H. and Adeli, H. (2018), "Novel Machine-Learning Model for Estimating Construction Costs Considering EconomicVariables and Indexes' . DOI: 10.1061/(ASCE)CO.1943-7862.0001570. © 2018 American Society of Civil Engineers.*

The whole data set of study were shared on UCI Machine Learning Repository. In this digital data warehouse, all data related to the study were shared with detailed excel files. All stages from the beginning to the end of the study, the data collected, the tests carried out, and the codes and techniques used, as well as which code and the program used to where have been explained.

In the following section, the changes in the journals in themselves are examined during the two periods compared.

5.1.13. Journal of Construction Engineering and Management

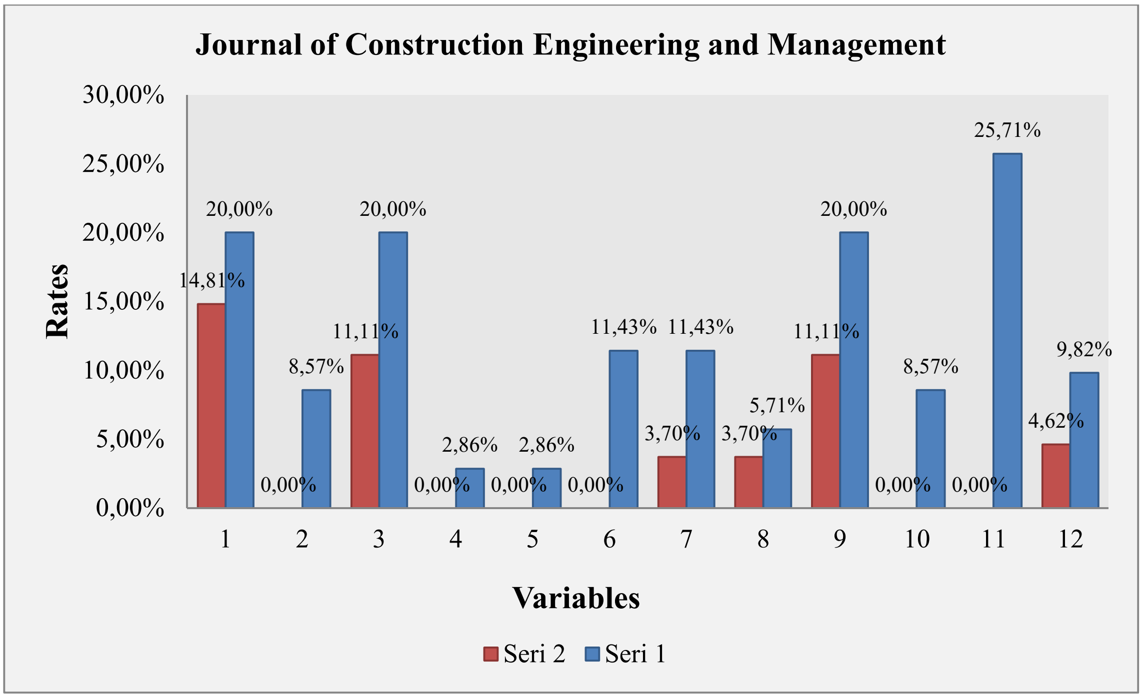

Figure 5.13. Rates of changings from 1984-2009 period to 2009-2019 period in Journal of Construction Engineering and Management Journal

Graph 1 shows the proportion of reported findings of the Journal of Construction Engineering and Management between the two periods. In this journal, a positive development is observed in terms of data sharing rate. An increase was observed in the number of data reported for all variables. Reported mean variable 14.81% to 20.00%, median variable 0% to 8.57%, SD variable 11.11% to 20.00%, skewness and kurtosis variables 0% to 2.86%, diagnostic test from 0% to 11.43%, correlation table data from

3.70% to 11.43%, raw data variable from 3.70% to 11.43 %, the percentage of converted variables increased from 11.11% to 20%, the number of reproducible articles increased to 8.57 percent and finally the data availability statement increased to 25.71%. We find the data availability statement only in this journal because it is the first project management magazine that obliges this part in the articles to be published since 2018.

5.1.14. Construction Management and Economics

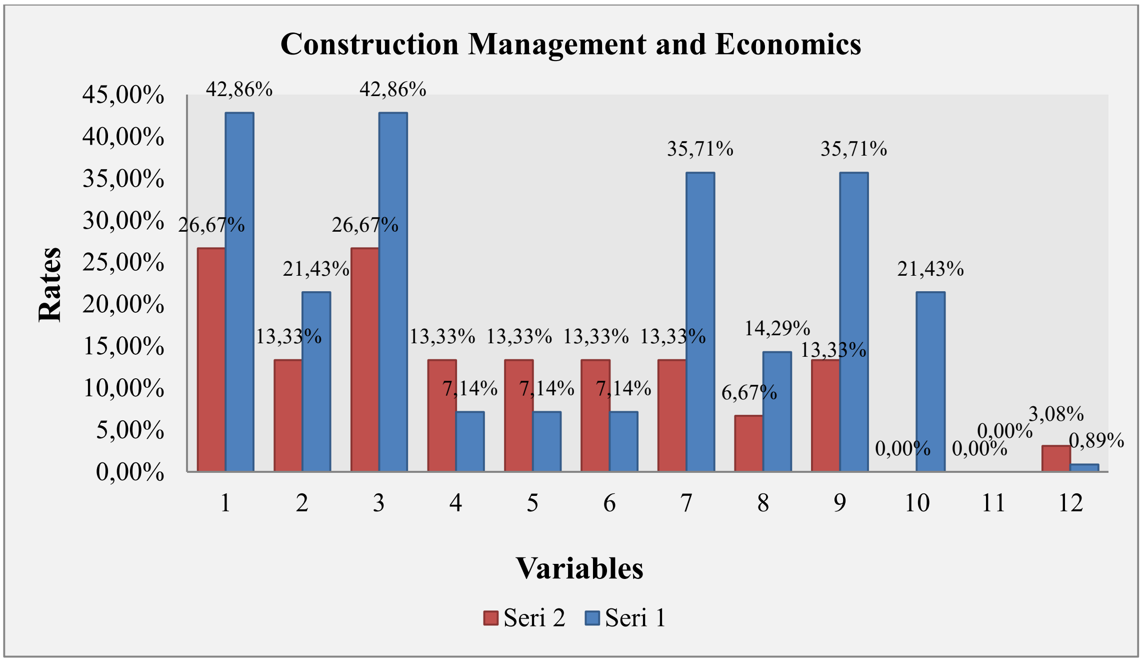

Figure 5.14. Rates of changings from 1984-2009 period to 2009-2019 period in Construction Management and Economics

In Graph 2, we see the share of findings of Construction Management and Economics for two periods. When we look at the graph, there was an increase in mean, median, standard deviation, correlation table, raw data, reporting of transformed variable data and the number of reproducible articles. Diagnostic tests, reporting of skewness and kurtosis data decreased from 13.33% to 7.14%. The ‘data availability statement’ section is not included in any of the articles published in either period.

5.1.15. Automation in Construction

Graph 3 shows the data from Automation in Construction. When we examine the graph, we see positive progress only in reporting standard deviation (12.50 percent to 20 percent) and correlation table (0 percent to 6.67 percent) data. The number of mean values reported decreases from 12.50% to 6.67% and the median decreases from 12.50% to 0%. There is no reported data in other variables.

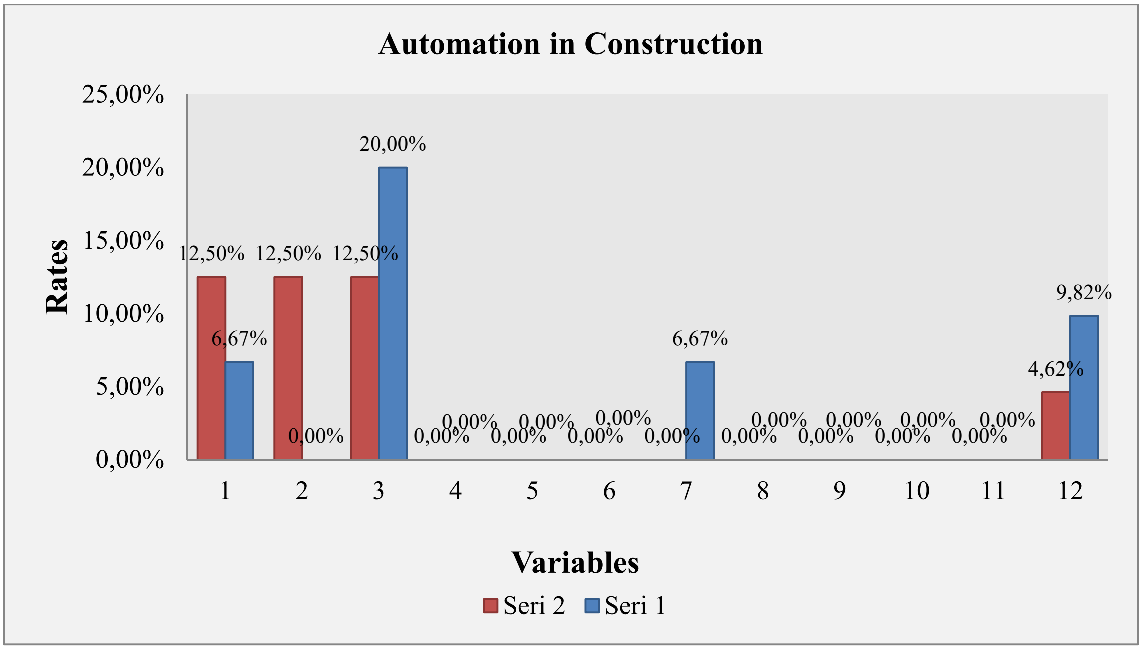

Figure 5.15. Rates of changings from 1984-2009 period to 2009-2019 period in Automation in Construction

5.1.16. KSCE Journal of Civil Engineering

Graph 4 shows the data of the KSCE Journal of Civil Engineering. When we examine the graph, there is an increase in the mean, standard deviation, correlation table and raw data findings reported. While no data were reported during the period of 1984-2009, these variables were reported in the articles published during the period of 2010-2019. Mean has increased to 23.08 percent, SD to 7.69 percent, correlation table to 15.38 percent and raw data variable to 7.69 percent. There is no data reported in other variables.

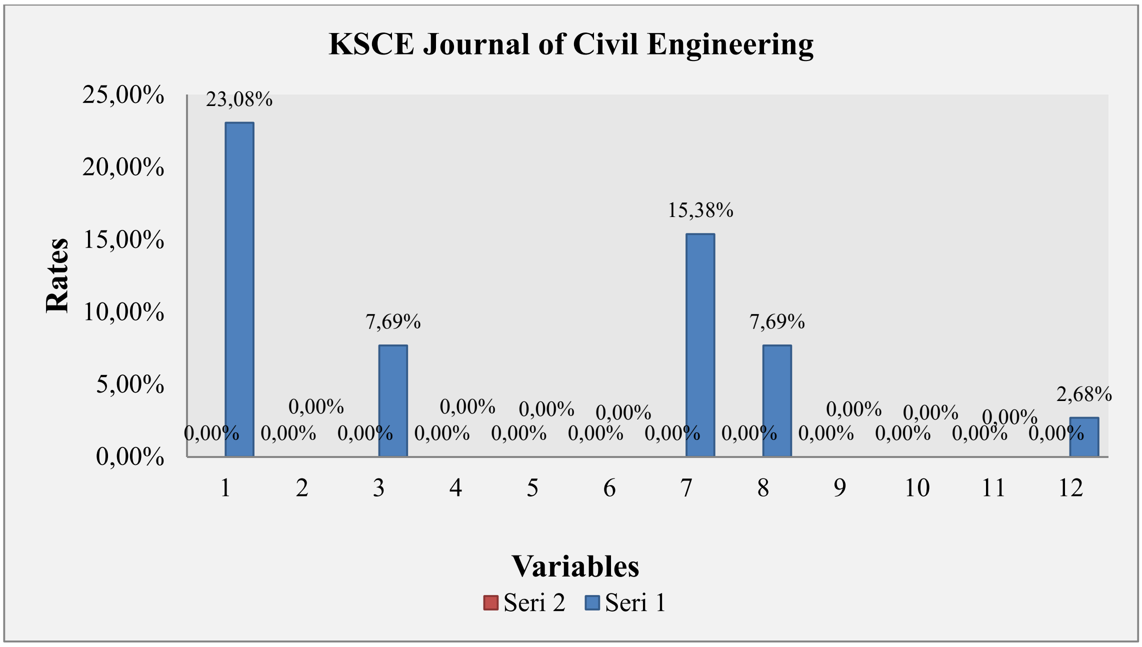

Figure 5.16. Rates of changings from 1984-2009 period to 2009-2019 period in KSCE Journal of Civil Engineering

5.1.17. Journal of Civil Engineering and Management

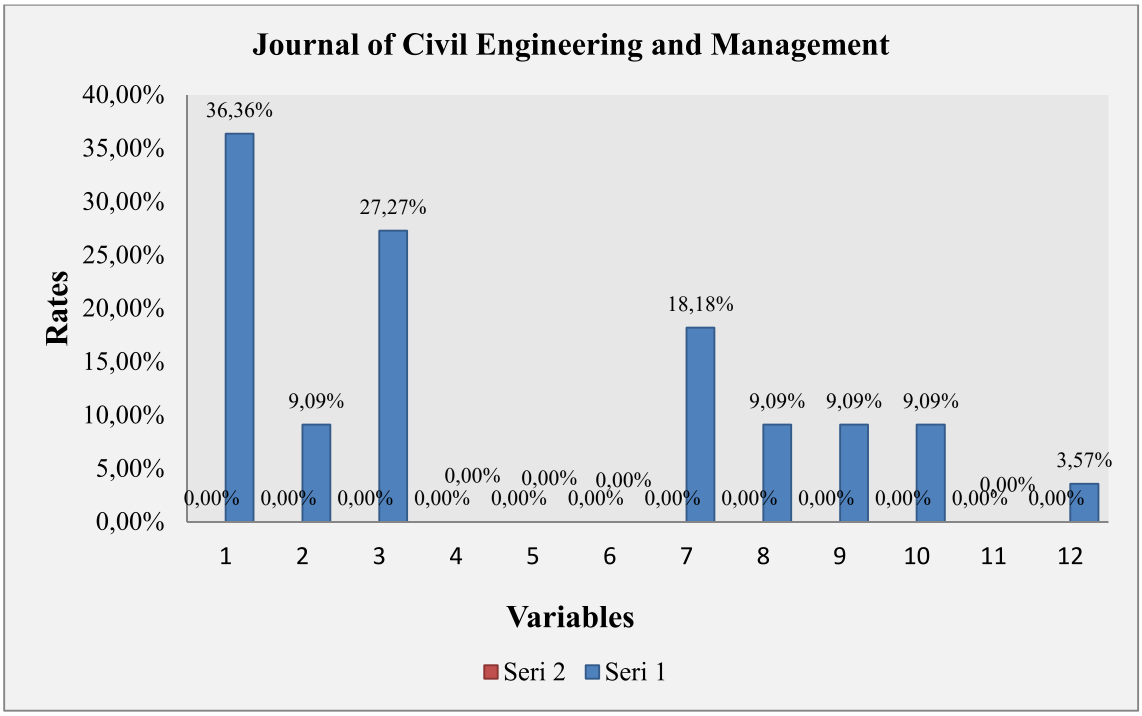

Figure 5.17. Rates of changings from 1984-2009 period to 2009-2019 period in Journal of Civil Engineering and Management

Graph 5 shows a comparison of the two terms of the Journal of Civil Engineering and Management. There are no data reported in the articles published during the period 1984-2009. In 2010-2019, we see the expected increase in reporting. There was no increase in reporting of skewness, kurtosis, diagnostic test data and the number of articles sharing the data availability statement only. The mean reported data increases to 36.36 percent, the median to 9.09 percent, the SD to 27.27 percent, the correlation table to 18.18 percent, raw data, converted variable data, and the number of reproducible articles increased to 9.09 percent.

5.1.18. Journal of Management in Engineering

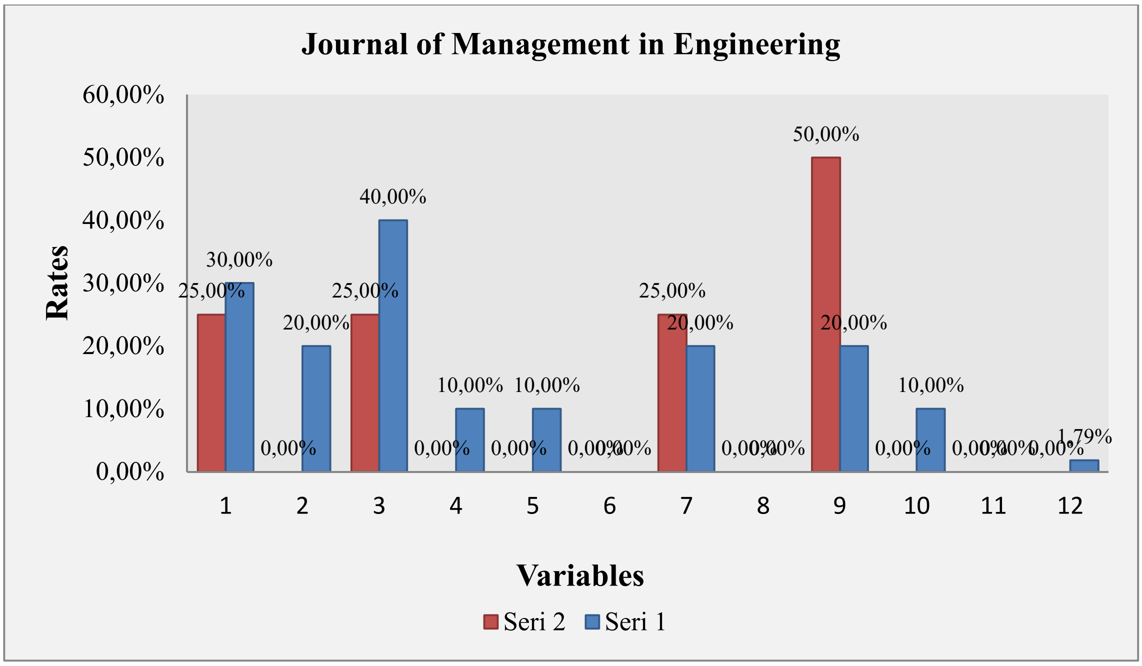

Figure 5.18. Rates of changings from 1984-2009 period to 2009-2019 period in Journal of Management in Engineering

Graph 6 shows the change seen in the Journal of Management in Engineering. When we examine the graph, it is seen that there is an increase in the number of reported data. While mean mean, median, standard deviation, skewness, kurtosis values and reproducible number of articles are increased, there is a decrease in the reported correlation table and transformed variable data. There are no reported data on diagnostic tests, raw data.

5.1.19. Canadian Journal of Civil Engineering

Graph 7 shows the proportion of variables reported in articles published in the Canadian Journal of Civil Engineering. The expected increase does not appear in the 2010-2019 period. Only the sharing of correlation table data increased. Reported mean and standard deviation data decrease from 60 percent to 12.50 percent, and skewness, kurtosis, diagnostic tests, and transformed variable data decrease from 20 percent to 0 percent. There are no reported data in other variables.

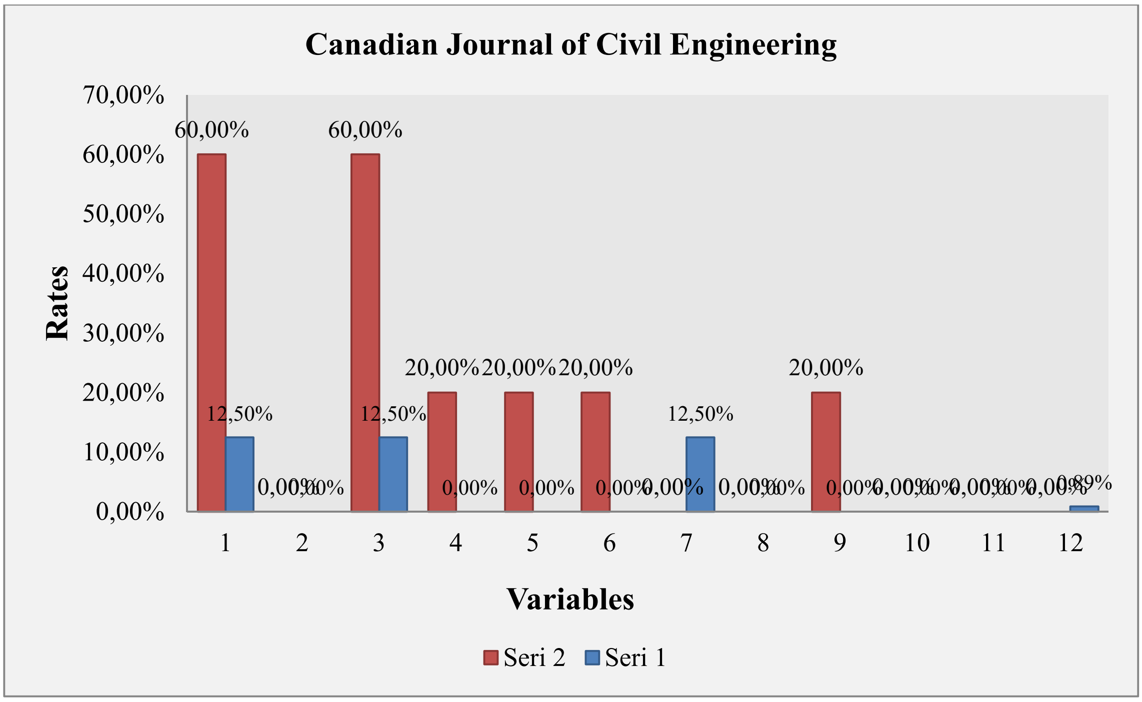

Figure 5.19. Rates of changings from 1984-2009 period to 2009-2019 period in Canadian Journal of Civil Engineering

5.1.20. Engineering, Construction and Architectural Management

Graph 8 shows the proportion of variables reported in articles published in Engineering, Construction and Architectural Management. While only standard deviation data were reported in the articles published in the period of 1984-2009, the graph shows that mean, SD, correlation table and transformed variable data were reported in 2010-2019 period. The number of mean and SD reported increase to 33.33 percent, and the correlation table and transformed variable data increase to 16.67 percent.

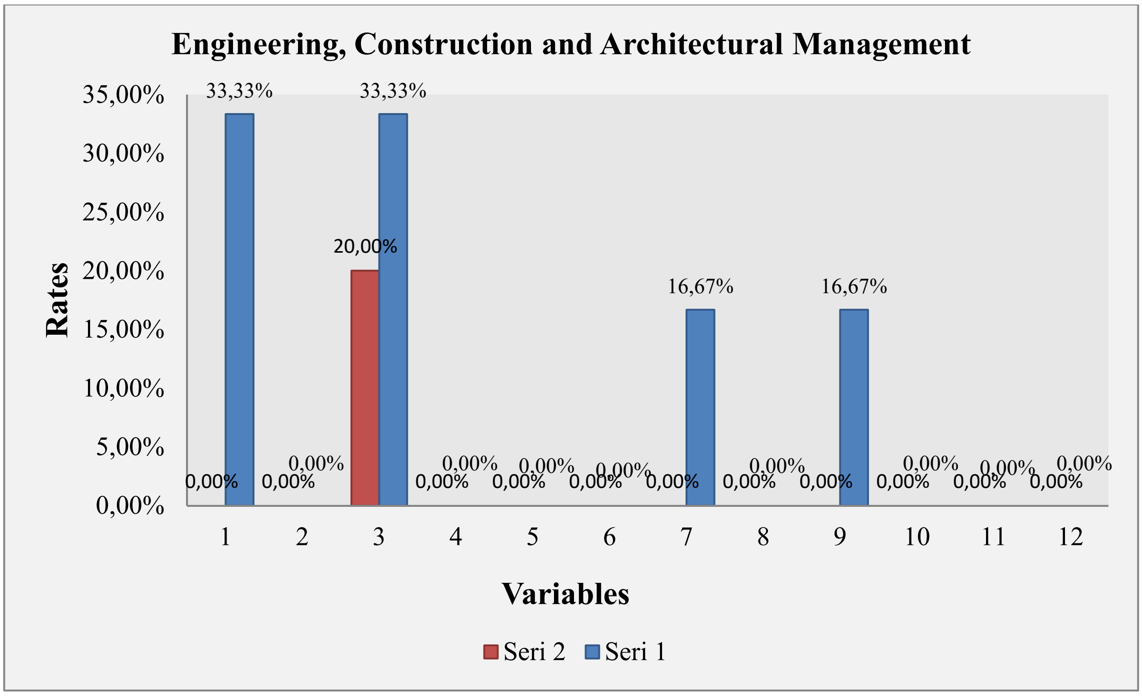

Figure 5.20. Rates of changings from 1984-2009 period to 2009-2019 period in Engineering, Construction and Architectural Management

5.1.21. Discussion

In recent years, the reproducibility of the study results has been discussed in many disciplines (Baker, 2012; Bissell, 2013). The inability to reproduce the study findings raises some doubts and concerns about the reliability of science and studies (Berg et al, 2017). In this thesis, this important and popular topic was discussed for research on cost estimation methods in project management. The concept of reproduction in the project management literature is a new issue that is still unknown. Therefore, there are very few articles on the subject in this field.

In previous studies, it is seen that the reproduction rate of the studies is very low, and often repeated results contradict the original results. This undermines confidence in published reports. Repetition of article findings is of great importance in terms of reliability, validity, and generalizability of empirical findings. However, in the project management literature, we find that empirical findings are not supported, fragmented, and empirical tests are inadequate. Unfortunately, the importance given to the reproduction of study findings, such as in the physical sciences, psychology, or medicine, is not shown in the field of project management.

For all the reasons mentioned above, we aimed to document the reproducibility of the findings in our study, to identify and report the reasons that prevent it from being repeated, and if possible, to compare the reported results of the study with the reported version and to see if the results are the same. For this purpose, 227 articles from 24 project and production management journals were divided into two different time periods (1984 -2009, 2010-2019). None of the 92 articles in the 1984-2009 period, in which data sharing was uncommon, provided the necessary data to reproduce. In the 2010-2019 period, although the concept of data sharing and reproducibility became widespread, the results of only 9 articles out of 135 were determined to be partially or completely reproducible. The articles reviewed are mostly high cited articles and are published in journals with high h indexes. Despite this, the rate of sharing the findings of the study with readers and other scientists was seen. Looking at the 227 articles reviewed, it is seen that the literature on cost estimation methods also faces the crisis of reliability. Because most of the articles did not report enough data to allow the findings to be reproduced. Because they were unable to reproduce, they raised doubts about the accuracy of the findings.

These studies were attempted to be reproduced using commonly used techniques, but if the findings cannot be reproduced even with the most commonly used techniques, studies used in more complex approaches may be less suitable for repetition. Authors should review the results of the research, check every data, and make the necessary reporting before publishing their work (Berg et al, 2017). If the authors do not pay attention to these issues and, on the contrary, the deliberate misrepresentation and opportunistic results, the replication findings are affected by this (Schwab and Starbuck, 2017). The way in which authors publish their studies and findings can only be understood by reproducing the results, this is necessary for the reliability of the study. There will always be a doubt for research results whose findings cannot be reproduced. Finally, this research was conducted for articles in 24 journals with an h-index in the range of 14 - 124, relatively inferior to high quality. Although the results of our research give information about the general situation, these results may not be valid for journals that are not included in the study.

Journals argue that recent policies and original research data should be published. Some journals do not even publish articles that do not share data. These steps are important to expand reproducibility. As Mittelstaedt and Zorn argue, “it is not worth multiplying, not worth knowing. The aim of the research is to contribute to science and to pioneer and assist in further studies. This can only be done with knowledge development and accumulation. As the duplication of the findings allows us to obtain new data external to the raw data, it will contribute greatly to the accumulation of knowledge. In this thesis, we looked at whether the articles about cost estimation methods can be reproduced. In Chapter 3, cost estimation methods are explained in detail, and as we have mentioned, the majority of the methods generate a prediction by analyzing historical data. When we look at article analysis, the most researched prediction methods in 227 articles are regression and neural networks methods. The following methods are obtained by analyzing past data. The studies in the articles are usually based on comparing two or more prediction methods and finding the best method. Each researcher argues that some methods are better, but when examined the articles, another researcher does not find the method that one researcher calls the best. In this case, it is important to share the findings of the study results. When reproducing the results, it can see which method is really the best and solve this confusion. However, since the data are not shared sufficiently, the number of reproducible studies is very small and this situation undermines the trust of the research results. In addition, since the findings cannot be reproduced, which is the most effective method is not known, and all these studies do not make sense and do not contribute to science and discipline because the accuracy of the results cannot be confirmed.

The purpose of dozens of estimation models and still many proposed models is to shorten the time spent on the traditional cost estimation method and give the closest results to it. While not everyone's goal is the same, keeping the study findings is inappropriate for this purpose. Creating a common pool of all study findings will be an important resource for future studies and will also save time for researchers. Because they will probably use this time and effort to improve the method, probably not wasting time collecting previously acquired data.

CHAPTER 6

CONCLUSION

The term reproducibility is a concept that has become popular in many literature over the last few decades. It is already widely used in fields such as psychology and medicine. Reproduction of the study results is important both for the control of the study results and for the reliability of the study. The concept of reproducibility is a newly introduced term in the project management literature and is not known much. Today, cost estimation methods are being developed to replace the traditional cost calculation method as reliable and faster than the traditional method. There are many methods that help the cost estimator.

In this thesis, were examined whether the studies related to cost calculation methods can be reproduced and the reliability of the research results of non-reproducible studies. Sample size is 227 articles. The studies in these articles were examined in accordance with the determined variables. It was examined how much of the study data was shared. As a result, only 3.96% of the articles were reproducible. The mean value of the shared data is 9,4347. No data is shared to allow the study results to be repeated.

Most of the cost estimation methods are based on historical data of projects. Therefore, if we want to develop the best estimation method, all researchers should collect the study data in a common pool. Thus, new methods can be developed without the hassle of collecting the same data again. Develop prediction algorithms by using data from this pool in existing methods.

As a result, in the field of cost estimation methods, researchers should allow more researchers to re-create their work by sharing more data so that the reliability of the study results is not compromised. Reproducible research should be encouraged through various policies.

APPENDICES

APPENDIX A

The list of the articles examined in the thesis is given below.

Adeli, H. and M. Wu. 1998. "Regularization Neural Network for Construction Cost Estimation." *Journal of Construction Engineering and Management* 124 (1): 18-23. doi:10.1061/(asce)0733-9364(1998)124:1(18).

Ahiaga-Dagbui, D.D. and S. D. Smith. 2014. “Dealing with construction cost overruns using data mining.” *Construction Management and Economics*, 32:7-8, 682-694, DOI:10.1080/01446193.2014.933854

Ahn, J., S. -H Ji, M. Park, H. -S Lee, S. Kim, and S. -W Suh. 2014. "The Attribute Impact Concept: Applications in Case-Based Reasoning and Parametric Cost Estimation." *Automation in Construction* 43: 195-203. doi:10.1016/j.autcon.2014.03.011.

Al Abo Omar, E. and Jean-Claude Mangin. 2002. "A new cost control model and indicators to measure productivity on building sites", *Construction Innovation*, Vol. 2 Issue: 2, pp.83-101, https://doi.org/10.1108/14714170210814720

Al-Harbi, K. M., D. W. Johnston, and H. Fayadh. 1994. "Building Construction Detailed Estimating Practices in Saudi Arabia." *Journal of Construction Engineering and Management* 120 (4): 774-784. doi:10.1061/(ASCE)0733-9364(1994)120:4(774).

Ali, S., T. Zayed, and M. Hegab. 2007. "Modeling the Effect of Subjective Factors on Productivity of Trenchless Technology Application to Buried Infrastructure Systems." *Journal of Construction Engineering and Management* 133 (10): 743-748. doi:10.1061/(ASCE)0733-9364(2007)133:10(743).

Amr A.G. Hassanein, Bahaee N.L. Khalil. 2006. "Building Egypt 1 – a general indicator cost index for the Egyptian construction industry", *Engineering, Construction and Architectural Management,* Vol. 13 Issue: 5, pp.463-480, https://doi.org/10.1108/09699980610690747

Ashuri,B. S. M. Shahandashti and J. Lu. 2012. “Empirical tests for identifying leading indicators of ENR Construction Cost Index.” *Construction Management and Economics,* 30:11, 917-927, DOI: 10.1080/01446193.2012.728709

Asmar, M. E., A. S. Hanna, and G. C. Whited. 2011. "New Approach to Developing Conceptual Cost Estimates for Highway Projects." *Journal of Construction Engineering and Management* 137 (11): 942-949. doi:10.1061/(ASCE)CO.1943-7862.0000355.

Aziz, A.R.S., and El Karriri, A. 2008. "Investigating the overhead costs in construction projects in Palestine", *Journal of Financial Management of Property and Construction*, Vol. 13 Issue: 1, pp.35-47, https://doi.org/10.1108/13664380810882066

Back, W. E., W. W. Boles, and G. T. Fry. 2000. "Defining Triangular Probability Distributions from Historical Cost Data." *Journal of Construction Engineering and Management* 126 (1): 29-37. doi:10.1061/(ASCE)0733-9364(2000)126:1(29).

Bansal, V. K. and M. Pal. 2007. "Potential of Geographic Information Systems in Building Cost Estimation and Visualization." *Automation in Construction* 16 (3): 311-322. doi:10.1016/j.autcon.2006.07.002.

Bayram, S. and S. Al-Jibouri. 2016. "Application of Reference Class Forecasting in Turkish Public Construction Projects: Contractor Perspective." *Journal of Management in Engineering* 32 (3). doi:10.1061/(ASCE)ME.1943-5479.0000421.

Bayram, S. and S. Al-Jibouri. 2018. "Cost forecasting using RCF: a case study for planning public building projects costs in Turkey." *International Journal of Construction Management*, 18:5, 405-417, DOI: 10.1080/15623599.2017.1333399

Bhargava, A., P. C. Anastasopoulos, S. Labi, K. C. Sinha, and F. L. Mannering. 2010. "Three-Stage Least-Squares Analysis of Time and Cost Overruns in Construction Contracts." *Journal of Construction Engineering and Management* 136 (11): 1207-1218. doi:10.1061/(ASCE)CO.1943-7862.0000225.

Cha, H. and D. Lee. 2018. "Determining Value at Risk for Estimating Renovation Building Projects by Application of Probability-based Fuzzy Set Theory." *Journal of Asian Architecture and Building Engineering*, 17:1, 63-70, DOI: 10.3130/jaabe.17.63

Chan, C.T.W. 2012. "The principal factors affecting construction project overhead expenses: an exploratory factor analysis approach." *Construction Management and Economics*, 30:10, 903-914, DOI: 10.1080/01446193.2012.717706

Chan, S. L. Corresponding author and M. Park. 2005. "Project cost estimation using principal component regression." *Construction Management and Economics*, 23:3, 295-304, DOI: 10.1080/01446190500039812

Chang, C. -Y and J. -W Ko. 2017. "New Approach to Estimating the Standard Deviations of Lognormal Cost Variables in the Monte Carlo Analysis of Construction Risks." *Journal of Construction Engineering and Management* 143 (1). doi:10.1061/(ASCE)CO.1943-7862.0001207

Chao, L.-C. 2010. "Estimating project overheads rate in bidding: DSS approach using neural networks." *Construction Management and Economics*, 28:3, 287-299, DOI: 10.1080/01446190903473782

Chao, L.-C. and C.-N Liou. 2007. “Risk-minimizing approach to bid-cutting limit determination” *Construction Management and Economics*, 25:8, 835-843, DOI:10.1080/01446190701393018

Chen, H. L. 2007. "Developing Cost Response Models for Company-Level Cost Flow Forecasting of Project-Based Corporations." *Journal of Management in Engineering* 23 (4): 171-181. doi:10.1061/(ASCE)0742-597X(2007)23:4(171).

Chen, J.-H, Li-Ren Yang , W. H. Chen and C. K. Chang. 2008. “Case-based allocation of onsite supervisory manpower for construction projects.” *Construction Management and Economics*, 26:8, 805-814 To link to this article: https://doi.org/10.1080/01446190802014778

Cheng, M. -Y, H. -C Tsai, and W. -S Hsieh. 2009. "Web-Based Conceptual Cost Estimates for Construction Projects using Evolutionary Fuzzy Neural Inference Model." *Automation in Construction* 18 (2): 164-172. doi:10.1016/j.autcon.2008.07.001.

Cheng, M. -Y, N. -D Hoang, and Y. -W Wu. 2013. "Hybrid Intelligence Approach Based on LS-SVM and Differential Evolution for Construction Cost Index Estimation: A Taiwan Case Study." *Automation in Construction* 35: 306-313. doi:10.1016/j.autcon.2013.05.018.

Chou, J. -S and J. T. O'Connor. 2007. "Internet-Based Preliminary Highway Construction Cost Estimating Database." *Automation in Construction* 17 (1): 65-74. doi:10.1016/j.autcon.2007.03.001.

Chou, J. -S, C. -W Lin, A. -D Pham, and J. -Y Shao. 2015. "Optimized Artificial Intelligence Models for Predicting Project Award Price." *Automation in Construction* 54: 106-115. doi:10.1016/j.autcon.2015.02.006.

Cirilovic, J., N. Vajdic, G. Mladenovic, and C. Queiroz. 2014. "Developing Cost Estimation Models for Road Rehabilitation and Reconstruction: Case Study of Projects in Europe and Central Asia." *Journal of Construction Engineering and Management* 140 (3). doi:10.1061/(ASCE)CO.1943-7862.0000817.

Doloi, H. 2013. "Cost Overruns and Failure in Project Management: Understanding the Roles of Key Stakeholders in Construction Projects." *Journal of Construction Engineering and Management* 139 (3): 267-279. doi:10.1061/(ASCE)CO.1943-7862.0000621.

Dursun, O. and C. Stoy. 2011. “Time–cost relationship of building projects: statistical adequacy of categorization with respect to project location.” *Construction Management and Economics,* 29:1, 97-106, DOI: 10.1080/01446193.2010.528437

Dursun, O. and C. Stoy. 2016. "Conceptual Estimation of Construction Costs using the Multistep Ahead Approach." *Journal of Construction Engineering and Management* 142 (9). doi:10.1061/(ASCE)CO.1943-7862.0001150.

Edwards, D. J., G. D. Holt and F. C. Harris. 2000. “Estimating life cycle plant maintenance costs.” *Construction Management & Economics*, 18:4, 427-435, DOI:10.1080/01446190050024842

Elmousalami, H. H., A. H. Elyamany, and A. H. Ibrahim. 2018. "Predicting Conceptual Cost for Field Canal Improvement Projects." *Journal of Construction Engineering and Management* 144 (11). doi:10.1061/(ASCE)CO.1943-7862.0001561.

Enshassi, A. S. Mohamed, I. Madi, 2005. "Factors affecting accuracy of cost estimation of building contracts in the Gaza Strip", *Journal of Financial Management of Property and Construction*, Vol. 10 Issue: 2, pp.115-125, https://doi.org/10.1108/13664380580001069

Faghih, S. A. M., & Kashani, H. 2018. "Forecasting construction material prices using vector error correction model." *Journal of Construction Engineering and Management, 144*(8) doi:10.1061/(ASCE)CO.1943-7862.0001528

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