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What are the most effective risk management strategies for mitigating delays in large construction projects?

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Working title/Abstract
In this research paper the most effective risk management strategies for mitigating delays in large construction projects will be discussed. Delays in any construction projects, be it big or small, are a significant risk for investors, contractors and project managers. If the projects are not completed in the agreed time frame they bare different penalties, for contractors involved in these projects. Therefore, large construction companies invest a lot of time and money into research to mitigate these delays. Having effective risk management strategies can lead to other future collaborations between the investor and the contractor, and help them plan for any possible setbacks that may occur during the construction process. Usage of technology, proper planning, established strategies, and communication between all parties involved in the construction project helps mitigate possible delays and ensure a smooth functioning of all construction processes. The results imply

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I. Introduction

Large construction projects are extremely important in developing modern society in terms of promoting economic growth by boosting production, generating more jobs and raising standard of living of citizens. These projects do so by advancing urban growth, improvement of electricity networks and water supply, as well as improvement of transportation systems. (Flyvbjerg et al., 2003). Nonetheless, it is widely known that in the construction industry there are often delays in the construction process that affect the time and resources spent on a project. Delays in any construction project can occur due to poor communication between contractors and suppliers, lack of planning, shortage of labor, unforeseen global occurrences such as global health crises and natural disasters. However proper planning and risk management strategies can help mitigate delays in the projects(Abd Aziz et al., 2022). This research paper aims to further explore the most effective risk management strategies in order to mitigate delays as much as possible in large construction projects. The research is important because it could help project managers on large construction projects to plan for any possible setbacks, when caused by any reasons mentioned above. It can also help improve customer and stakeholder satisfaction and optimize resources used in the large projects. Also, communication, information systems and technology, financial literacy and management, establishment and enforcement of law and order can help mitigate potential delays (Abd Aziz et al., 2022).

II. Research objectives

This research aims to explore most effective management strategies to mitigate project delays. There are many studies exploring causes of project delays and some even dealing with potential solutions to the issues. Previous studies were focused on examining certain aspects of a investor - contractor relationship in a setting of a developed economy such as the U.S., or EU and even in some cases less developed countries such as Ghana (Wepari et al., 2024). Fewer studies included firms in Bosnia and Herzegovina that deal with large projects and to whom occur many risks. This paper will therefore utilise data to examine possible risk mitigation strategies as the aim is to explore what are the most efficient strategies that can be used.

This paper has 2 main objectives, which are:

- To examine effect of technology usage and budgeting in mitigating project delays in large projects
- To examine effect of implementing environmental practices in mitigating delays in construction.

III. Research hypotheses

The hypotheses are as follows:
H01: Technology implementation does not have a positive effect in mitigating project delays.
HA1: Technology implementation has a positive effect in mitigating project delays.
H02: Budgeting does not have a positive effect in mitigating project delays.
HA2: Budgeting has a positive effect in mitigating project delays.
H03: Environmental practices do not have a positive effect in mitigating project delays.
HA3: Environmental practices have a positive effect in mitigating project delays.

IV. Literature review

There are many studies conducted assessing reasons for possible large construction project delays. Majority of the reasons, for project delays, were found to be project management, materials, technology, lack of finance, improper planning, futile site supervision, lack of commitment and communication, rising prices of materials and services (Fallahnejad, 2013; Khoshgoftar et al., 2010; Rafieizonooz et al., 2015). While other studies have found different implications for project delays, such as output of the workers, on-site delivery of the materials, low quality equipment and monetary limitations (Hamzah et al., 2012). The aforementioned factors are technical risks, which can be mitigated by having thorough reviews of designs, rigid quality control and selection of higher quality materials, as well as, having those materials properly stored and handled and by utilizing a software that manages risks and improves outcomes of a project (Altshuler &Luberoff, 2003; Siemiatycki, 2009; Ward & Chapman, 2003). These studies have highlighted root causes of the project delays while other studies such as Rahman et.al. (2013), Yap et.al. (2018), Yap and Shavarebi (2019) explored strategies that would alleviate project delays. They found that useful strategies are consisted of contractors' site management, improving communication, and focusing on human and managerial part of the construction industry. Moreover, communication management can be improved by faster response, which will reduce costs and risks (Muthuveeran et al., 2022).

Some authors imply that project supervision in the early stages by project managers in large construction projects can mitigate delays (Banobi and Jung, 2019). Information systems and technology can be a useful tool to facilitate supervision on worksites. While technology advancements are important in every step in the construction project there is much room for improvement left (Henriques et al. 2020). These studies indicate that there are effective risk management strategies that can help mitigate possible delays for large construction projects. Also, the solutions presented in these studies are in line with the aim of this paper, which is to examine the most effective strategies that mitigate project delays.

Furthermore, financial constrains cause delays in large construction projects and the management needs to make sure that there is sufficient funding for a certain project (Soomro et al. 2019). Some of the financial risks are cost overruns in which expenses occurred exceed the initial budget. Reasons for such issues arises from poorly estimated costs, price increases for materials and services that are not expected, or some changes made by investors during a specific project (Flyvbjerg et al., 2003). Moreover, fluctuations in a budget can also happen due to unexpected economic conditions in a country where project is taking place and this can require further funding (Makovšek&Moszoro, 2018).

This implies that budgeting is an important part of possible project delay mitigation strategies and it needs to be integrated in early stages of negotiation process between participants i.e., the investor and contractor. It also implies that risks need to be accounted for and planned in a financial estimate part of a project.

Besides financial constraints, that pose risks on a project, there are some other factors that have a risk factor such as pollution and resource depletion. These risks have a large impact on environment and managing them includes arranging the usage of rigorous measures that protect the environment (Ward & Chapman, 2003). Some of the examples include having design practices which are sustainable and incorporating environmental assessments (Siemiatycki, 2009).

There is also a possibility of social risks in terms of disrupting local communities which can lead to conflicts. In some projects there is a need to relocate inhabitants and businesses which can lead to challenges in terms of logistics (Flyvbjerg et al., 2003). There is a matter of safety of the construction workers and local residents, therefore there is a need to have strict measures and protocols that will mitigate these types of risk (Makovšek&Moszoro, 2018). This implies that social risks can be extremely harmful for a project if not accounted for. It also implies that in order to solve these risks there needs to be engagement with all stakeholders in order to effectively resolve their concerns. There needs to be appropriate compensation to locals in case of relocation challenges. Moreover, this means that in order to mitigate social risks there needs to preparedness for certain issues that arise when dealing with stakeholders, as well as readiness to implement changes, if necessary, without breaking the budget.

Moreover, there are successful and unsuccessful projects, and both experience delays. (Banobi and Jung, 2019). The authors examined the causes of project delays in successful and unsuccessful projects and potential ways to mitigate delays. The study explored 82 owner - side experts and 106 contractor – side experts. Findings suggest that in successful projects delays are caused by late permits from authorities and vandalism, while poor supervision by the owner, poor owner's planning, top contractor management failure to plan are causes for delay in unsuccessful project delays. Furthermore, Banobi and Jung (2019) suggest that mitigation strategies in successful projects are close supervision of a project, appropriate management of logistics, timely site visits, support of top management of a contractor. In unsuccessful projects Banobi and Jung (2019) suggest that mitigation strategies are appropriate and timely planning and budgeting, procurement of materials in a timely manner and completing project design in a timely manner. This implies that communication between investor and a contractor is quite important. One of the ways to improve communication is through usage of technology. A lot of construction business rely on usage of technology to help them mitigate risks, however majority of business have yet to start implementing it.

Besides, there are a few strategies to manage risk in order to minimize their impact on the project. Risk management needs to be efficient and addressed swiftly (Lawrence, 2024). One of the first steps is to identify hazards that can have an impact on the project. Such hazards or risks are financial, technological, environmental, and social. Contractors need be able to create a list of hazards, different methods to be able to solve mitigate potential risks (Ward & Chapman, 2003). One of ways these risks can be mitigated is through usage of risk registers which can list all the identified risks with their prospective assessments, mitigation measures and plans for monitoring (Flyvbjerg et al., 2003).The following step is to assess the risks. This is done in way when a risk is discovered their likelihood is to be evaluated alongside recognizing their probable consequences. However, focus is mostly given to those risks that carry a larger impact.

In this step qualitative and quantitative analytical techniques are used (Winch, 2010). Mitigation is the process of creating plans to lessen the probability and effect of risks. These can be creating backup plans or transferring risk via contracts or insurance. Mitigation is necessary in order to keep timeline of the project and its budget (Flybjerg et al. 2003). Monitoring is another step that is crucial in order to make sure that risks are managed effectively and that any new risks can be identified timely. It is done continuously (Makovšek&Moszoro, 2018).

Also, it is important to use an approach that can identify potential failures / risks, asses their effects, and to provide ways to solve them proactively (Makovšek&Moszoro, 2018). This approach is known as Failure Mode and Effects Analysis (FMEA). Furthermore, scenario planning is another useful tool in mitigating risks. It helps to identify them and develop contingency plans so there is preparedness for unpredictable events (Altshuler &Luberoff, 2003). This implies that timely planning along with the usage of certain measures can help mitigate risks or at least lessen their impact on a project.

Lawrence (2024) did a case study in which different risk mitigation strategies were used. The author compared different ways selected companies dealt with risks. Specifically, author examined the following cases: the case of the Big Dig (Central Artery / Tunnel Project) in Boston, the Hoover Dam in southwestern U.S., the expansion of the Panama Canal. All of these large projects had risks in terms of budget (financial risk), time constraints, environmental risks and safety risks, engineering issues, water supply risks and material supply risks. Financial risks were mitigated by early financial planning in terms of having fixed price contracts which made sure that contractors and supplier of materials were familiar with their obligations financially and were motivated to perform their duties on time and subsequently managed to mitigate time constraints. Environmental risks were mitigated by assessing the environment through monitoring of air quality, soil and ground water while using ecological materials to comply mitigate environmental risks (Lawrence, 2024). Ullah et al. (2024) suggest that political environment is a key factor in managing risk in large construction projects, especially for international contracting firms. Tariq and Gardezi (2023) state that the majority of the problems or causes of project delays lie in poor communication between clients and contractors, financial problems of the clients or possible changes made by the clients.

V. Research design and Methodology

This paper aims to examine most effective risk management strategies for mitigating delays in projects. It will use primary data that will be collected through a cross - sectional survey in which data is analyzed from a population at a single point in time (Wang & Cheng, 2020). The survey was distributed to 30 companies in Bosnia and Herzegovina, meaning this is the target audience.

The standard selection of firms will be based on a number of years of experience and that will be at least 5 years. Moreover, survey will have the following sections: information about respondent, mitigation strategy information - technology, mitigation strategy information - budgeting / finance, causes of delays (budget constraints, lack of technology usage, unexpected events or errors), mitigation strategy information - environmental practices, experience in the industry, as well as client delays and years of experience of an engineer. Independent variables will be technology usage (T), budgeting / finance implementation (F), environmental practices (EP), experience (E), client delays (CD) while project delays (PD) will be dependent. This implies that the model will be as follows:

PD = T + F + EP + E + CD +e[1]

The survey was created in which respondents used Likert scale. The Likert scale is a scale that is used to evaluate behaviors, opinions and/or attitudes quantitatively. In this research paper one point was very low, two points low, three points medium, four points high and five points for very high. The survey was distributed to 30 respondents via email. Respondents were informed that they will remain anonymous. The survey was collected from October 21st to October 31st. The respondents were partners of our family ownedconstruction company, who are also in the field of construction and work frequently in large construction projects.

VI. Empirical results

6.1. Introduction

This section provides descriptive statistics to understand the dataset better, Cronbach's alpha to understand reliability of the data, and model findings to explore whether or not model provided previously is statistically significant.

6.2. Descriptive statistics

In the table below descriptive statistics is presented for six variables. The column 'variable' lists all the variables, i.e., the dependent one and independent variables. Sample size is 'N' and it represents total number of observations, which in this case is 30 companies in Bosnia and Herzegovina.

Variable	N	Mean	Std. Dev.	Min	Pctl. 25	Pctl. 75	Max
Project_Delays	30	3	1.2	1	2	4	5
Usage_of_Technology	30	3.1	1.2	1	2	4	5
Financial_Review	30	2.7	1	1	2	3	5
Client_Delays	30	3	1.1	1	2	4	5
Years_of_Experience	30	2.9	0.91	1	2	3.8	5
Environmental_Practices	30	2.7	1.1	1	2	3	5

Table 1 Descriptive statistics. Source: Authors' calculation

6.2.1. Project Delays

For this variable mean or the average is 3, which implies that companies rated this variable in the middle of 1 to 5, further implying moderate delays. Standard deviation is 1.2, which is one the highest in the group of variables. This means that there is some variability in the way companies responded to project delays, as answers are spread around the mean. Minimum and maximum are 1 and 5, indicating that the responses fluctuated between lowest and highest ratings. Also, 25th and 75th percentiles are 2 and 4, which means that the

[1]e stands for errors that occur that are outside of control of a subject

middle 50% percent of the responses are between these values. This further indicates that half of the companies rated project delays between 2 and 4 (slightly lower and higher ratings).
6.2.2. Usage of technology
For this variable mean is 3.1, which is the highest of all variables. This means that companies rated this variable slightly above the middle point, which implies a rather positive review of technology usage. Standard deviation is 1.2, which indicates that there is a certain degree of variability in the responses of the companies. This means that some companies rated technology usage high on the scale, while others rated it low. Minimum and maximum are 1 and 5, which means that responses span around the entire scale. This implies that there are different perceptions of technology usage among the companies. 25th and 75th percentiles are 2 and 4, which is similar to project delays and means that technology usage is perceived as either slightly lower on the scale or higher. Also, the companies were asked what kind of technology they use majority was using drones, while only a few used some kind of software.
6.2.3. Financial review
For this variable mean is2.7 which is one of the lower values, implying that financial reviews are seen as less intensive or rigorous compared to technology use or project delays.
Standard deviation is 1 which is slightly lower than two previous variables. This means that there is less variation in the responses. Minimum and maximum are 1 and 5, which is the same as other variables. This means that financial review is seen on a broad range, indicating either higher commitment to budgeting/finance or a lower commitment to it. 25th and 75th percentiles are 2 and 3, which is different than the two preious variables. This means that majority of the responses are assorted around the middle point of the scale. This further implies that this factor was rated neutral or a bit below the average.
6.2.4. Client delays
For this variable mean is 3, which means that client delays are quite moderately rated, and further imply that there is a degree of delay in client responses. Standard deviation is 1.1, indicating a decent amount of variability and consistency in responses, as data is not as spread around the mean as in project delays. Minimum and maximum are 1 and 5, which means that responses are ranging from lowest to highest values. This could imply that experiences with clients very widely. 25th and 75th percentiles are 2 and 4, which means that the middle 50% percent of the responses are between these values. Further indicating that some clients cause minimal delays (hence the value 2), and other cause more delays (hence the value 4).
6.2.5. Years of experience
For this variable mean is 2.9 implying that on average respondents have a moderate experience level. Standard deviation is 0.91 which is one of the lowest of the variables. This means that years of experience are consistent with less extreme outliers. Minimum and maximum are 1 and 5, indicating that full range is existent, however majority of the companies cluster near the mean due to standard deviation being low. 25th and 75th percentiles are 2 and 3.8, showing that the middle 50% of the respondents have between 2 and 4 years of experience. This indicates that there is a concertation around moderate levels of experience.

6.2.6. Environmental practices

For this variable mean is 2.7, which is the same as financial review. This further implies that environmental practices are not highly rated as others. Standard deviation is 1.1, which is similar to client delays, indicating moderate variability in the responses. Minimum and maximum are 1 and 5, meaning that there is a full range of answers. Further showing that some respondents hold environmental practices low in regard, while others see it highly. 25 the and 75th percentiles are 2 and 3, indicating that some rate environmental practices highly and majority average or below.
Overall, it can be concluded that there are different responses across the variables, mostly for project delays, usage of technology and client delays. This is indicated by higher standard deviations. While, years of experience is more consistent among the respondents. Variables like financial review and environmental practices have lower averages, likely indicating areas where respondents feel there could be improvements.

6.3. Cronbach's alpha
Cronbach's alpha gives an understandable way to measure if or not a score is reliable or if the variables in a dataset are closely related. The value of Cronbach alpha lies between 0 and 1. The result of .70 and above is good, .80 and above is better, and .90 and above is best (Taber, 2018). Metrics used in the reliability analysis are: raw alpha, std.alpha, G6 smc, average r, s/n, ase, mean, sd, median r. Raw Cronbach's alpha is 0.81, which indicates a high level of internal consistency among the items. This suggests that the items are reliably measuring an underlying construct. Generally, an alpha of 0.7 or above is considered acceptable, while 0.8 or above is considered good. Standardized Cronbach's alpha is also 0.81. This value accounts for any standardization (e.g., if items were measured on different scales). Since it's equal to raw alpha here, it suggests

that the items are fairly consistent in terms of scaling. Guttman's lambda 6 (G6), or Squared Multiple Correlation (SMC), is an alternative reliability measure. A G6 close to alpha (0.8 here) supports that your alpha is a stable reliability estimate. Average inter-item correlation of 0.45 indicates moderate correlations between items. An average inter-item correlation between 0.3 and 0.5 is often desirable, as it suggests the items are related but not redundant. Signal-to-noise ratio is 4.1, meaning the reliable variance (signal) is about 4 times greater than the error variance (noise). A higher ratio indicates more reliable items, with 4.1 being quite strong. Alpha Standard Error (ASE) of 0.055 is the standard error of Cronbach's alpha. A lower ASE indicates a more precise estimate of alpha, and 0.055 is quite low, which enhances confidence in your alpha result.
The mean of the items is 2.9, which gives an idea of the overall level of responses if each item is on a similar scale. Standard deviation (SD) of 0.81 shows the spread of the item responses, indicating moderate variability. Median inter-item correlation of 0.46 aligns closely with the average inter-item correlation (0.45). This consistency shows that most items correlate similarly with each other, reinforcing a reliable construct measurement.
Overall with a Cronbach's alpha of 0.81 and other supporting reliability measures (like high S/N and moderate inter-item correlations), the items or variables seem to have good internal consistency. This analysis suggests that the items effectively measure a coherent construct and are suitable for inclusion as a composite measure in further analysis.

Metric	Value
raw_alpha	0,81
Std.alpha	0,81
G6(smc)	0,8
Average_r	0,45
S/N	4,1
ase	0,055
mean	2,9
sd	0,81
Median_r	0,46

Table 2 Cronbach's Alpha. Source: Authors' calculation.

6.4. Model findings
In this section model findings are presented. They are presented in sections, meaning a table is created for residuals, coefficients and model fit statistics.
6.4.1. Residuals

Residuals represent the differences between observed and predicted values. They give an idea of how well the model fits the data. In this model, results are displayed below.

Static	Residuals
MIN	-1,59003
1Q	-0,44222
MEDIAN	-0,04511
3Q	0,54279
MAX	1,90768

Table 3 Residuals. Source: Authors' calculation.
Distribution of residuals is represented by these values: minimum is -1.59 and is the smallest residual, implying that some predictions were up to 1.59 units below the actual values. While 1Q or the first quantile is -0.44, which indicates that 25% of the residuals are below this value. Median is -0.05 showing the median residual, suggesting the distribution of residuals is fairly centered around zero. Third quantile or 3Q is 0.54 and that

indicates that 75% of residuals are below this value. Maximum is 1.91 and this is the largest residual, indicating that some predictions were up to 1.91 units above the actual values.

6.4.2. Coefficients

Coefficients, each of them help to explain the effect of a predictor or independent variable on the dependent variable while holding other variables constant. In this model the results are the displayed below. Estimate column shows the estimated effect of each independent variable on the dependent. Usage of technology, if increased by 1 increases the project delay for 0.399. While financial review if increased by 1, increases project delay by 0.13113. Project delays are increased by 0.1381 if client delays are increased by 1. Years of experience have a negative effect on project delays. While environmental practices increase dependent variable by 0.25312. However, the only statistically significant variable is usage of technology, as p-value < 0.05. The p-value that is used in a t-test for the coefficients helps to understand whether a coefficient is significantly different than zero. In this model, this indicates that there is strong evidence that usage of technology has an impact on project delays. Moreover, standard error helps to measure the variability / precision of the estimate. If the values are lower it is more precise. The lowest value is for usage of technology. The t-value helps to understand whether the data in the model suggest evidence against the null hypotheses or not. The highest value is for usage of technology (2.08). This indicates that there is enough evidence to reject the null hypothesis at 0.05 significance level.

Variable	**Estimate**	**Std_Error**	**t_value**	**Pr(>|t|)**
(Intercept)	0,43984	0,65015	0,677	0,5052
Usage_of_Technology	0,3992	0,19189	2,08	0,0483*
Financial_Review	0,13113	0,19225	0,682	0,5017
Client_Delays	0,1381	0,20791	0,664	0,5129
Years_of_Experience	-0,02804	0,23479	-0,119	0,9059
Environmental_Practices	0,25312	0,19253	1,315	0,201

Table 4 Coefficients. Source: Authors' calculations.

* is the significance level for p < 0.05

Further, the evidence supports the alternative hypothesis which concludes that technology usagehas a positive effect onmitigating project delays. Other variables are not statistically significant, and null hypotheses for financial review and environmental practices cannot be rejected. However, this was a rather small sample so this was to be expected.

6.4.3. Model fit statistics

This helps to understand how well model fits the data. Residual standard error represents the average amount by which observed outcome deviate from predicted values of the model (Kenton, 2020). In this model residual standard error is 0.8838 indicating that actual values differ by 0.8838. Moreover, multiple R squared and adjusted R squared are 0.5189 and 0.4186 indicating that 51.89% and 41.86% of the variance in the dependent variable is explained by independent variables. This implies a moderate fit. R squared and adjusted R square show how well dependent variable is explained by independent ones (Muralidhar, 2023). F-static and p-value are 5.176 and 0.002316 which means that model as whole is statistically significant. Further, independent variables explain a significant amount of variance in project delays. However, this was a sample size of 30 companies, indicating that in the future this number should be larger to capture the project delay mitigation strategies better. The results are displayed below.

Static	Value
Residual standard error	0,8838
Degrees of freedom	24
Multiple R-squared	0,5189
Adjusted R-squared	0,4186
F-statistic	5,176
p-value	0,002316

Table 5 Model fit. Source: Authors' calculation.

VII. Conclusion

This paper aimed to investigate whether mitigation strategies such as usage of technology, budgeting/financial review, environmental practices have effects on project delays. This paper utilized data to examine possible risk mitigation strategies as the aim is to explore what are the most efficient strategies that can be used. The method used to collect the data was a survey, and the sample size was 30 companies in Bosnia and Herzegovina. The results were interesting and showed how usage of technology has a positive effect on project delays. Moreover, the results also indicate that H01 cannot be accepted, and that HA1 can be accepted which indicates that technology usage has positive and statistically significant effect as a mitigation strategy on project delays. However, other variables had no statistical significance indicating that effects budgeting/financial review and environmental practices have a lower effect on project delays, while years of experience have even negative effect on project delays since the relationship is inverse. Those statistically insignificant variables do not allow to reject the H02 and H03, meaning we fail to reject those hypotheses.

This could be due to small sample size. Moreover, majority of the technology used were drones. This implies that companies could work on using even better technology to mitigate project delays. Therefore, we can say that the first objective that was set to examine effect of technology usage and budgeting in mitigating project delays in large projects was met. The results also imply that other mitigation strategies were not of much importance in mitigating project delays. This means that the second objective that was set to examine effect of implementing environmental practices in mitigating delays in construction was not met. The results indicate that technology usage is rather important. Moreover, the results also imply that more variables could be added and sample size could be bigger in order to understand project mitigation strategies in more depth. There is also a possibility of adding a political factor, as seen in Ullah et al. (2024), into future analysis as that could be used to gain a more comprehensive view and understanding risks being involved into construction projects and to help create possible solutions that would minimize risks.

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