

Article

# Construction Projects Duration Derivatives, Correlations Analysis Justified by Frequency Count and Questionnaire

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**Abstract:** The performance of construction projects is often measured by the triad of cost, quality, and time. However, many projects fail to meet these criteria, leading to significant cost overruns and delays. This research investigates the micro-level factors contributing to time and cost overruns in construction projects. Utilising a mixed-methods approach, the study combines qualitative data from a comprehensive survey of field professionals and quantitative data from a detailed case study of a hospital construction project in northern Jordan. The findings reveal that changes during the project lifecycle, particularly those stemming from requirement modifications and miscommunication, are the primary drivers of delays. While the number of workforce personnel influences activity duration, its impact is secondary to that of changes. The study underscores the critical need for effective change management and communication strategies to mitigate delays and enhance project performance. These insights offer valuable contributions to the construction industry, providing practical recommendations for improving project outcomes through better management practices. The research emphasizes the importance of workforce quality, skill, and contractual arrangements, thereby presenting a comprehensive analysis of the factors affecting construction project success.

**Keywords:** Construction Project Management, Change Management, Project Performance, Quantitative Analysis, Qualitative Analysis,

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## INTRODUCTION

The three pillars that justify project performance are cost, quality, and time (Big & Small, 2013) as it is not uncommon for construction projects to run low on one or more of these three pillars, triggering the interest of research in the field (Mansfield et al., 1994; Meng, 2012), actually according to Standish Group (Big & Small, 2013) in 2012 project statistics in the united states of America shows that forty-three percent of construction projects did not meet the success criteria by either compromising time or cost indicating overruns, more precisely fifty-nine percent of the previously mentioned percentage were cost overruns and seventy-four percent were time delays, as (PMI, 2000) identifies a projects' success by meeting its predefined quality, under the budget set, and within time.

Considering construction projects nature, it proposes multiple complex interactions in numerous aspects of the project, hence the project duration is affected by these factors (Dursun & Stoy, 2011a; Dursun & Stoy, 2011b).

Over the course of years, extensive research has been pulled on time and cost overruns in construction projects, these researches examined the macro-factors of these projects, however, this research paper will examine the factors affecting a construction project on a micro level, as instead of assessing multiple project criteria, it will take a deeper dive into a selected core project phases and factors affecting them.

## LITERATURE

Construction project duration was studied from numerous categories, Chan validated previous models in different geographical areas using simple linear regression ruling the type of client owning the project as one of the factors, of either the project being publicly or privately funded, in addition to the building cost (Chan, 1999; Chan, 2001), moreover Hoffman uses multiple linear regression results were summed to the air command presence or not, the use of air education and training command or not, region, type of procurement (in house or construction agent), and the building cost (Hoffman et al., 2007), also Ogunsemi and Jagboro found that building cost alongside client type as the factors affecting the duration (Ogunsemi & Jagboro, 2006), the outcome of Love multiple linear regression diverts from what was discussed earlier to further details, the drivers according to the study conducted are the gross floor area, number of levels, both tender and call for tender types, also work type

(newly built or renovation) (Love et al., 2005), Chan results also mention the construction project costs (Chan & Chan, 2003; Chan & Kumaraswamy, 1995). The facade, height of the building, site nature and the type of housing scheme, Thomas Ng study agrees with the previously mentioned building costs, building and tender type, however, it pushes forward to include contract type (eg: lump sum contract) (Thomas, 2001) which Kaka and Price research also aligns with these results (Kaka & Price, 1991), Bromilow research also agrees on the two pillars of building costs and client/owner type (Bromilow et al., 1980), Dursun and Chan also does not fall far from the tree to confirm the same previous results of building cost and client, facility and project types (Chan & Kumaraswamy, 1995; Dursun & Stoy, 2011a; Dursun & Stoy, 2011b), as for the outcome of Khosrowshahi and Kaka multiple linear regression research shows more detailed results, to include horizontal access, buildability type (simple or complex), scope of works, work type, frame type, number of units, floor type, abnormality occurrence, commence month of construction, alongside building costs (Khosrowshahi & Kaka, 1996).

Woodhead divides time overruns into three categories, ones which neither party has control over, others that the construction owner has control, and the third which the contractor is the one with power to influence and control (Antill & Woodhead, 1991).

Overruns that neither party has control over are usually included in the risk evaluation conducted by the contractor prior to taking the project, resulting in no grounds whatsoever for a monetary recompense from either party, besides a completion date extension so contractor's protected from having delayed completion claims, resulting in liquidated damages (Kaming et al., 1997).

As for factors that the owner has control over, the contractor must be fairly compensated in both terms of cost and time, lastly, where the contractor has the influence, the contractor takes full responsibility (Kaming et al., 1997).

Delays in construction projects occur due to a significant number of variables within, while these variables may not always result in late project completion, however, still, they usually increase the construction project's cost (Kaming et al., 1997).

These variables vary from weather to material estimates; cost and shortages, craftsmen production rate, equipment production rate, skill shortages, locational restrictions, design changes, inadequate planning, project complexity, contractor's lack of experience; whether geographical, project type or local regulations (Kaming et al., 1997). Discussing

briefly the relevant factors that will be examined later throughout the article.

Construction projects are often exposed to all weather extremes, and both extremes can have a toll on project duration, as it is not often perceived, a hot climate results in a lower output due to the toll it on mental and physical energy (Mountjoy, 1975), accurate estimates of material, equipment and labour, are important for cost estimates, however the data usually shared is only useful as a guide and not consistent enough to be utilized for planning, in less developed countries, where such data is not shared, historical data is considered (Kaming et al., 1997). Changes in construction projects are inevitable, and these changes can come as a result of various factors at any point of the project, moreover, they are considered one of the main factors causing project budget overruns and delays (Owais, 2022; Kaming et al., 1997).

Labour also has its challenging characteristics, skills and motivation within the labour derives productivity, in developing countries, problems have been identified after conducting an intensive investigation Olomolaiye, 1988).

According to Kaming, Olomolaiye, Holt, and Harris, the predominant factors influencing time overruns in Indonesian high-rise construction are low labour productivity, design changes, resource shortages and inadequate planning (Kaming et al., 1997).

As for Dursun & Stoy, their study on German building projects concluded that the main derivatives are gross floor area and construction cost (Dursun & Stoy, 2011a; Dursun & Stoy, 2011b), which is aligned with the results of other literature reviewed earlier, additionally, the results confirm that location of the construction should be considered which also aligns with Nkado results (Nkado, 1995).

Lastly both Dursun & Stoy and Kaming, Olomolaiye, Holt, & Harris agree project managers' experience and management effectiveness should not be discounted (Dursun & Stoy, 2011a; Dursun & Stoy, 2011b; Kaming et al., 1997).

## DATA COLLECTION AND ANALYSIS

The data of this research was gathered in both states of qualitative and quantitative, In the first part, a questionnaire was shared with over 600 relevant field professionals from diverse experiences and backgrounds varying in location, project size, and knowledge area, to expand the sample size and gather a multiregional input, the data threshold for the questionnaire to be considered sufficient was a

minimum of 100 responses, which the later results are a representation for, the outcome of this questionnaire will be used to validate the previous factors discussed in literature.

100% of the sample is qualified with a Bachelor's degree or higher, of which 24.3% are PMP-certified (Figure 1).

68.5% of the sample are civil engineers, while the rest is divided into other relevant fields as the figure 2 shows.

The career level/experience of the group was split into 4 different groups based on the total number of experience years, additionally, the project sizing experience was divided into 3 groups based on the overall project budget (Figure 3).

The diversity of the sample spectrum from educational background qualification and specialization to professional experience level and size, assures a wide spectrum representation that is not governed by the usual constraints of having a single level perspective, additionally, the sample is collected across multiple regions, hence the data is not a region-specific, rather than field-specific running a cross-border practice trend (Figure 4).

Furthermore, previous research output only considers multiple project comparisons, and specific market studies, in this research we will be examining the influence of the same factors but within the same project life cycle, throughout a case study of a hospital multistory building in northern Jordan, and discussing the outcome and impact on project phases, throughout a correlation analysis and frequency count measure.

The sampled professionals were asked questions assessing three areas with relevance to the case study (Table 1).

The case study is a mid-size construction project, consisting of two zones, each zone has the exact same repetitive essential work activities and design, like, framework, rebar, and concrete pouring, data analyzed is for 3 basements and 3 above the ground floors, the data of relevance retained from this project are mainly the daily reports, which included all the dates, resources and activities related information, of which about 700 reports were collected, in order to standardize the phases examined, only main skeleton structure activities were considered to maintain the level of detail applicable to the majority of construction projects, additionally, two variables were filtered and gathered out of the reports, labour numbers per activity (craftsmanship) and change occurrences.

In general, for the first variable, there should be a negative correlation between the number of workers of a certain craft with the duration of completion of this craft activity, which can be considered as the

null hypothesis of the correlation analysis, also the calculation is made based on 95% confidence level. The daily reports were translated into the following data format, **Date**, **Report Number**, **Order Type**, **Floor Number**, **Activity Type**, **Work Zone**, **Work Process**, **Structural Element**, **Project Manager**, **Civil Engineer**, **Assistant Engineer**, **Foreman**, **Common Construction Labour**, **Carpenter**, **Blacksmith**, **Post-Tension Engineer**, **Post-Tension Worker**.

Sample of formulating 222 reports reviewed out of the total project reports for selected phases (Table 2).

In the table 2 the order type was split into two categories **Change Order** and **Normal Order**, as for work processes, **S** indicates the start of works, **IP** in progress, and **F** for finish, and the same logic applies to the structural element **Wall**, **Column**, **Beam**, **Slab** and so on.

Additionally, actual duration was measured by checking the start and the end date of activities, and compared to the project's preplanned duration and their variance (Table 3).

Later the planned vs actual data was accumulated and formulated into the work zones (Table 4).

Since the construction phase did not include the level of detail to specify the count of each craftsman working on which activity on a specific day, hence we relied on the average number per floor of the certain zone.

Finally, the computed data above is integrated in a format that serves the correlation analysis classified by activity, below is a sample for the Rebar activity (Table 5).

As for the last part of the analysis, a frequency count between Normal and Changes was measured after the correlation analysis.

## RESULTS

As the table 6 shows, a negative correlation was found between 5 out of 8 activities examined, which translates to finding a relationship between the time and number of workers, however since the p-value overpasses the 5% in the majority of the activities, and the 95% confidence level was not met, we fail to reject the null hypothesis.

Hence the correlation was found to be insignificant, and by conclusive reasoning, if the first variable has no influence, the second variable should, as a result, be the influencing factor of the overall project duration, thus a frequency count was measured to examine the percentage of normality during the studied period life cycle (Figure 5).

44% of the project duration was within changing environments and only 56% was a normal workflow

day, thus it is reasonable to conclude that the changes did influence the project duration performance, up on classifying the change types and frequency it was found that almost one-third of the changes are due to miscommunication and almost two-thirds were due to changes in requirements, while the weather and controlled changes only accounted for almost 10% as the pie chart shows (Figure 6).

The previous case study results align with the professionals' feedback received in the questionnaire, as shown below, when asked about the main project derivatives, 65.8% validated changes regardless of their type in comparison to only 27.9% for the workforce, as for the rest which was left to be filled upon the sampled group freedom, all the answers accumulates to both (Figure 7).

Of the 65.8% that identified changes as the main derivative of project duration, 45% verified change orders as the highest impact regardless of being influenced by either the client, the design, or the contractor (Figure 8).

As for the parts of the sample who chose workforce, 35% referred to the number of provided labour and equipment, 31% accounted for the quality and skill of these equipment and workers, and 34% see that the subcontracting agreement type is the main influencing factor (Figure 9).

## DISCUSSION

This research addresses a critical concern in construction project management: the impact of various factors on project performance, particularly focusing on time and cost overruns. The investigation is rooted in the understanding that project success is traditionally measured by the three pillars of cost, quality, and time, as highlighted by the Standish Group (Big & Small, 2013). The study leverages both qualitative and quantitative data to validate factors previously discussed in the literature and to examine them within a specific project lifecycle.

### Literature Insights

The literature review highlights that construction project duration and performance are influenced by a myriad of factors, ranging from client type and project cost to specific project characteristics such as gross floor area, number of levels, and contract type. Studies by Chan, Hoffman, and Ogunsemi underscore the significance of these variables in different geographical and project contexts (Chan, 1999; Chan, 2001; Hoffman et al., 2007; Ogunsemi

& Jagboro, 2006). Additionally, factors such as weather, material estimates, labor productivity, and project changes (Antill & Woodhead, 1991; Kaka & Price, 1991; Dursun & Stoy, 2011a; Dursun & Stoy, 2011b) further complicate the landscape of construction project management.

### **Empirical Data Analysis**

The empirical component of this research involved a comprehensive survey of 111 field professionals and an in-depth case study of a hospital construction project in northern Jordan. The diverse sample, encompassing various educational backgrounds, professional experiences, and regional contexts, provided a robust basis for analysis.

### **Correlation Analysis**

The correlation analysis sought to understand the relationship between the number of workers and the duration of construction activities. The hypothesis was that an increase in the number of workers would reduce the duration of activities. The findings were mixed:

- A negative correlation was observed in five out of eight activities, suggesting a relationship between workforce numbers and activity duration.
- However, the p-values indicated that these correlations were not statistically significant, failing to reject the null hypothesis.

These results imply that while workforce numbers do play a role, they are not the sole or dominant factor affecting project duration.

### **Influence of Changes**

A significant portion of the project duration (44%) was affected by changes, with changes in requirements and miscommunication being the primary drivers. This aligns with the survey results, where 65.8% of professionals identified changes as the main determinant of project duration. Within this group, 45% pointed to change orders as the most impactful, regardless of the source (client, design, or contractor).

### **Workforce Considerations**

Although changes were identified as the primary factor, workforce-related issues were also significant. Respondents emphasized the importance of the number of workers and equipment, the quality and skill of the workforce, and the nature of subcontracting agreements. These factors, while secondary to changes, nonetheless contribute to overall project performance.

## **CONCLUSIONS**

The comprehensive analysis of this research underscores the multifaceted nature of construction project management. Key conclusions include:

1. **Dominance of Change Factors:** Changes during the project lifecycle, particularly due to requirement modifications and miscommunication, are the most significant factors affecting project duration. Effective change management and improved communication strategies are essential to mitigate these impacts.

2. **Workforce Quality and Management:** While the number of workers influences project timelines, the quality, skill, and contractual arrangements of the workforce are equally important. Investment in skilled labor and high-quality equipment, coupled with favorable subcontracting agreements, can enhance productivity and reduce delays.

3. **Enhanced Planning and Risk Management:** Comprehensive planning that includes detailed risk assessments and considers potential changes can improve project resilience. This proactive approach can help anticipate and manage the factors that lead to time and cost overruns.

To improve project performance, the construction industry should focus on:

- **Robust Change Management:** Implementing standardized protocols for managing changes can help minimize disruptions. This includes clear documentation, regular stakeholder updates, and the use of integrated project management tools.
- **Improved Communication:** Establishing clear communication channels and regular updates can reduce the incidence of miscommunication and its subsequent impact on project timelines.
- **Quality Workforce Deployment:** Ensuring a skilled and well-equipped workforce, supported by effective subcontracting agreements, can lead to better project outcomes.
- **Comprehensive Planning:** Detailed planning that includes robust risk assessments can help anticipate potential issues and manage them proactively.

Future research should explore these factors in different contexts and project types to validate the findings and develop tailored strategies for various construction environments. By addressing the key determinants identified in this study, the construction industry can improve project performance, reduce overruns, and achieve greater success in meeting project goals.

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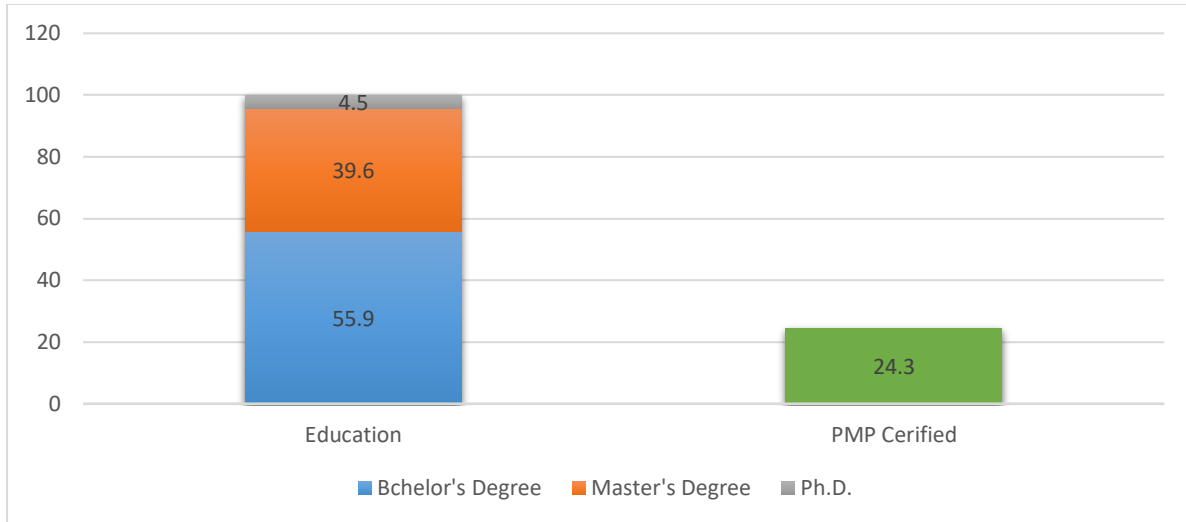


Figure 1  
**Sample Size Technical Qualification**  
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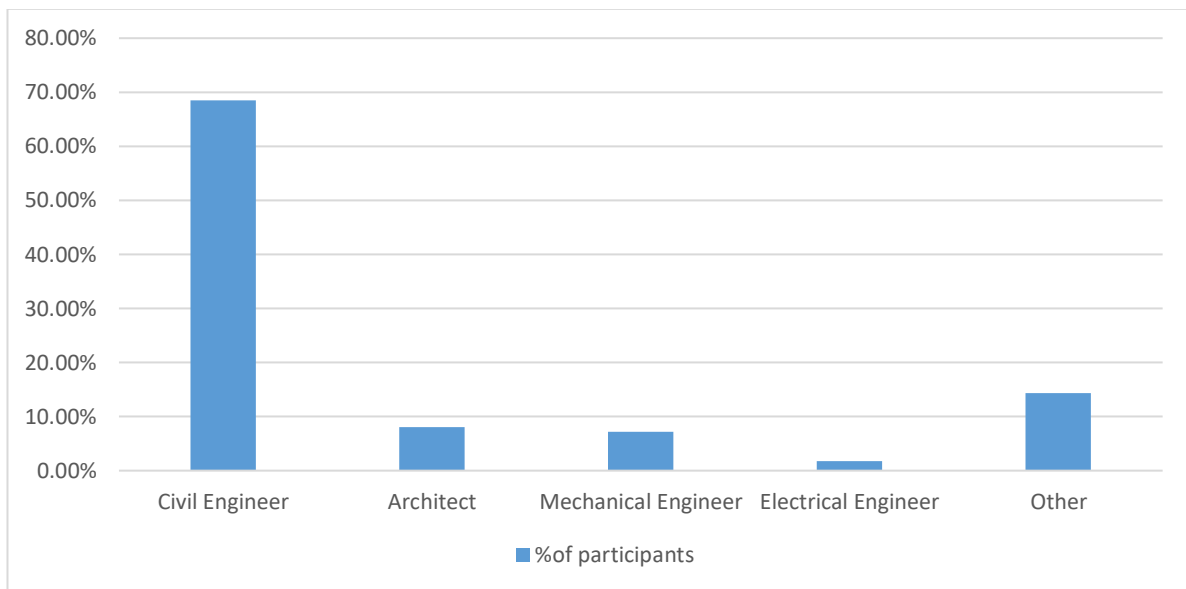


Figure 2  
**Participants Educational Background**  
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Figure 3  
**Professional background and roles of the sampled group**  
 Source: generated by the author

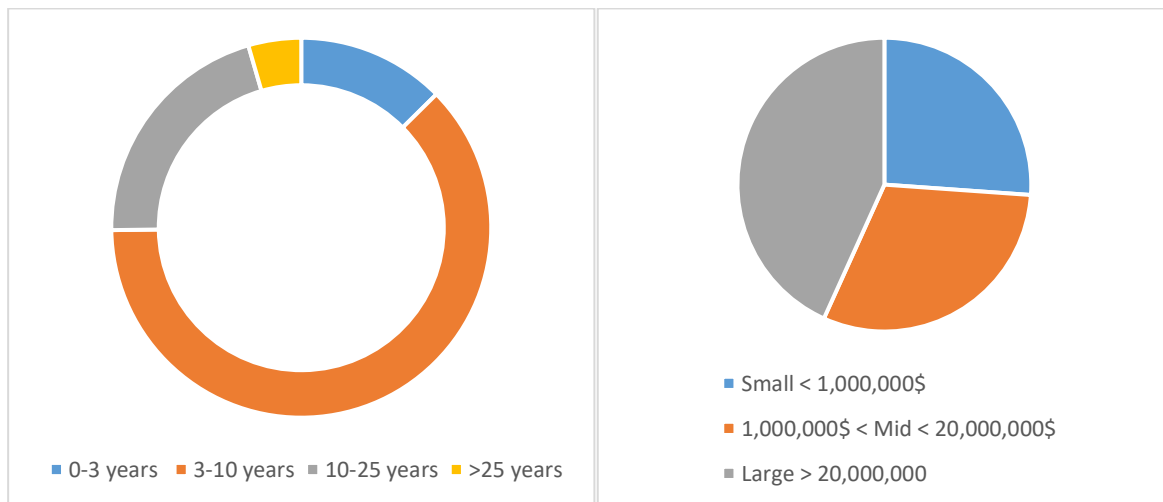


Figure 4  
**Career level & Project size**  
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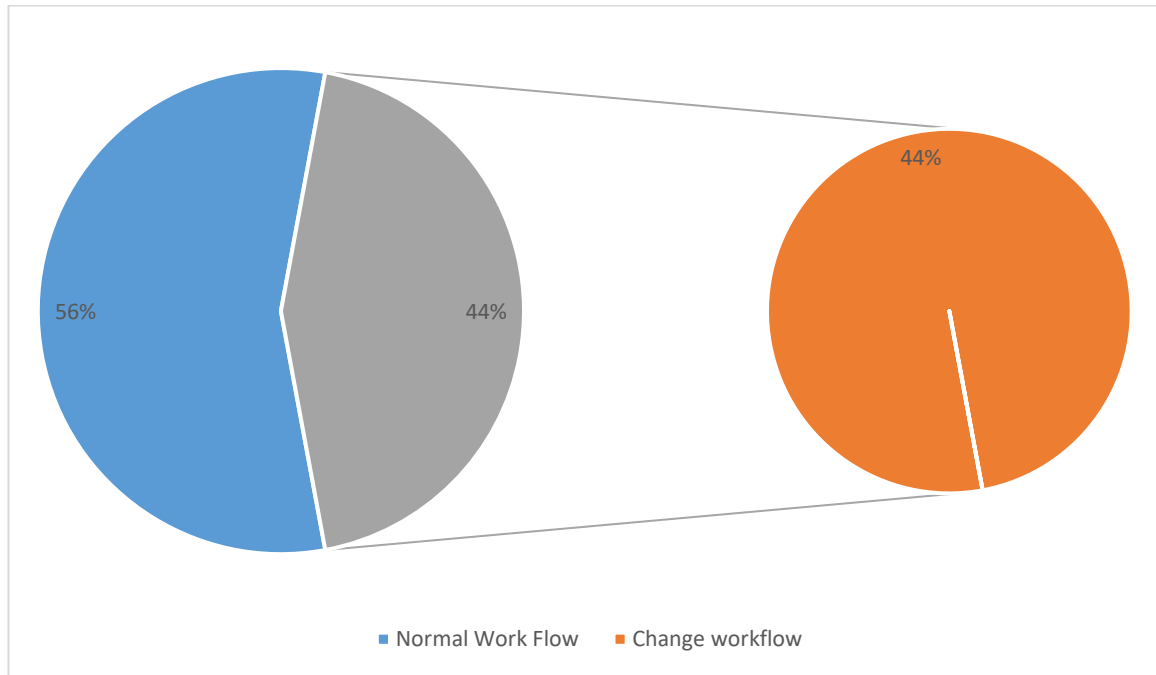


Figure 5  
**Frequency**  
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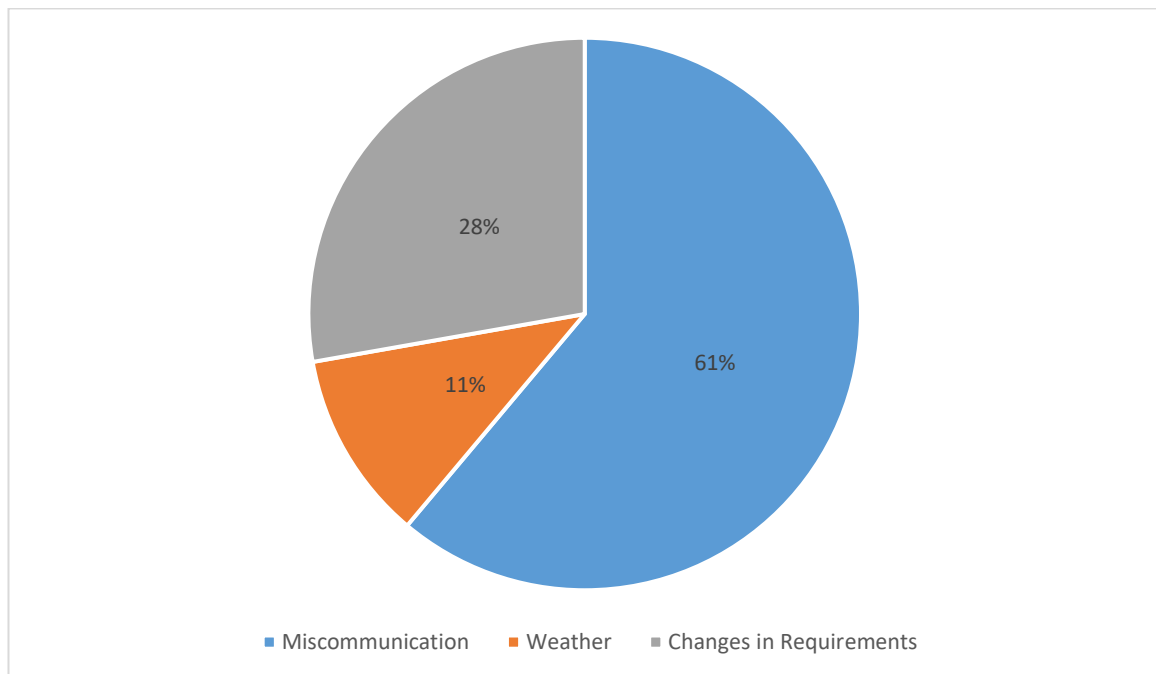


Figure 6  
**Changes in Workflow**  
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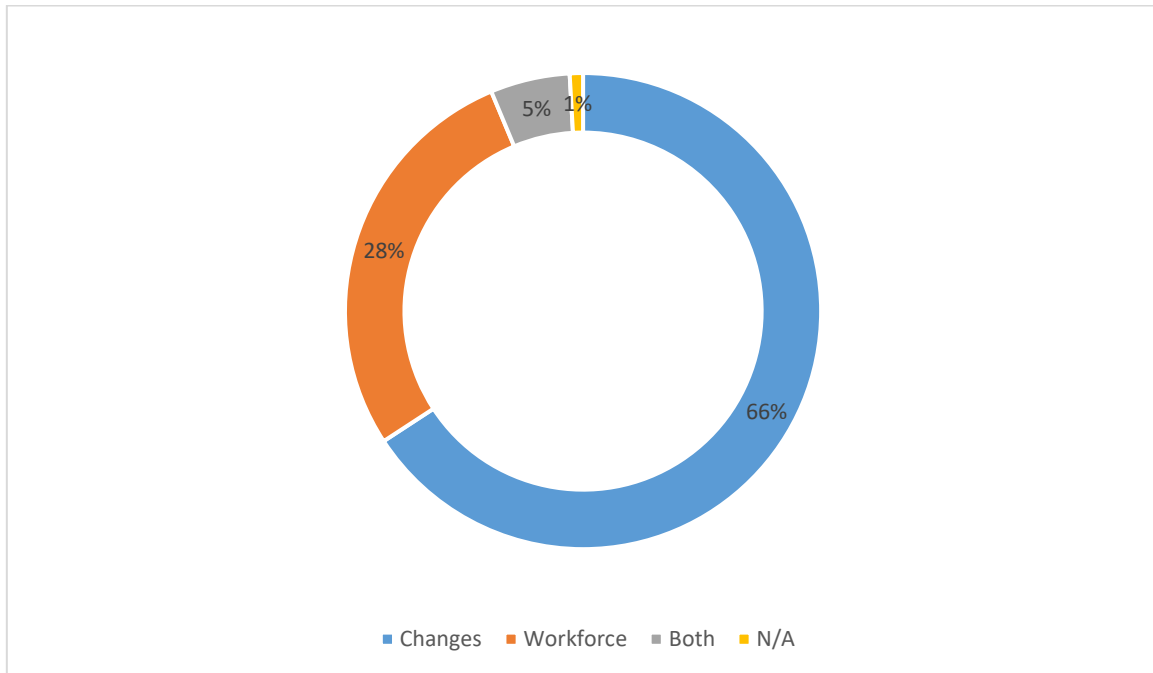


Figure 7  
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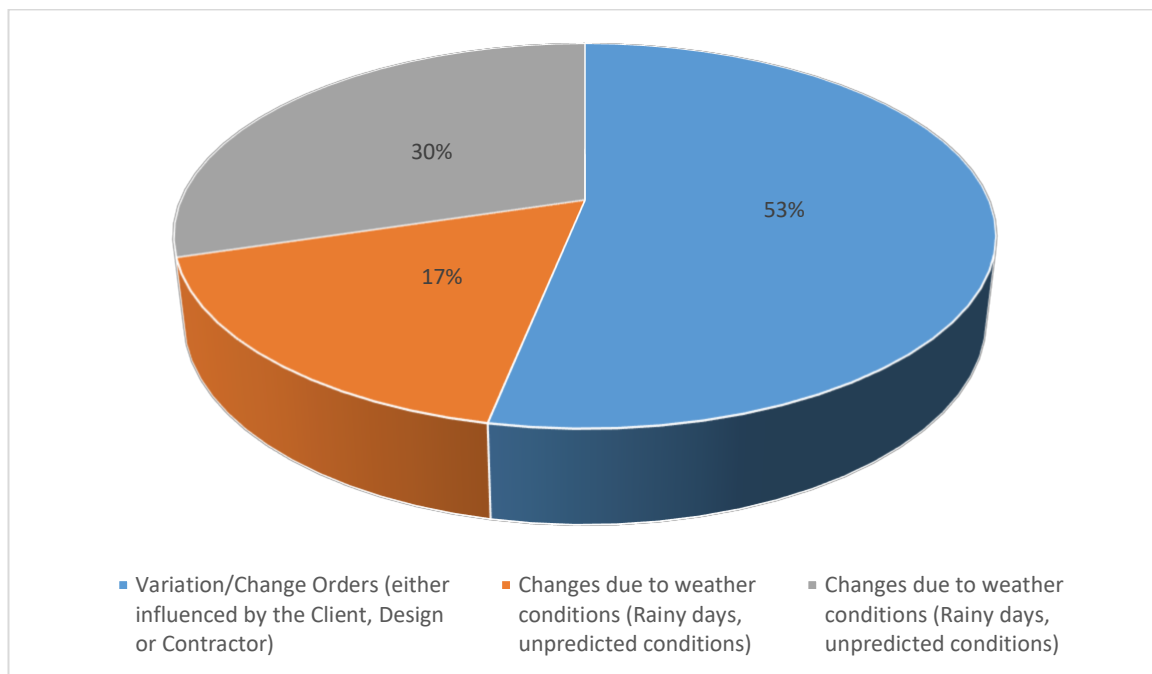


Figure 8  
**Changes**  
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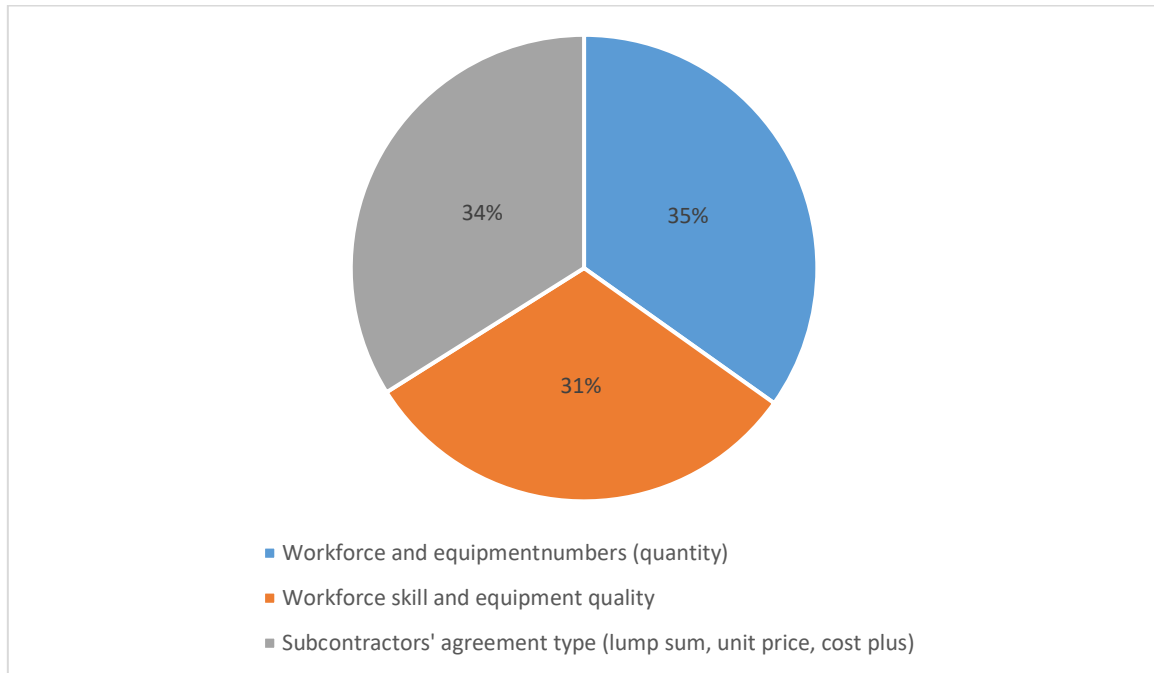


Figure 9  
**Workforce factor**  
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Table 1

**The sampled professionals were asked questions assessing three areas with relevance to the case study**

Question	Constraint
In reference to your experience, which of the following do you consider is the main project duration derivative?	<ul style="list-style-type: none"> <li>• Changes (Weather, Client, Variation/Change Orders, Special Site Conditions)</li> <li>• Workforce (Numbers, Skills, Agreement Type, Subcontractors)</li> <li>• Other (open answer)</li> </ul>
If your previous answer was changes, which of the following changes will have the biggest impact on project performance especially duration?	<ul style="list-style-type: none"> <li>• Variation/Change Orders (either influenced by the Client, Design or Contractor)</li> <li>• Changes due to weather conditions (Rainy days, unpredicted conditions)</li> <li>• Changes due to special site conditions (i.e: unexpected issues in the excavation works, laws and regulations)</li> <li>• Other (open answer)</li> </ul>
If your previous answer was workforce, which of the following reasons will have the biggest impact on project performance specially duration?	<ul style="list-style-type: none"> <li>• Workforce and equipment numbers (quantity)</li> <li>• Workforce skill and equipment quality</li> <li>• Subcontractors' agreement type (Lump Sum, Unit Price, Cost Plus, Time and Materials)</li> <li>• Other (open answer)</li> </ul>

Table 2  
**Sample of formulating 222 reports reviewed out of the total project reports for selected phases**

D	RN	OT	FN	AT	WZ	WP	SE	PM	C E	A E	FM	CCL	CP	BS	PT E	PTW
28-Aug-19	186	N	B1	FW	1	IP	W	1	4	3	3	4	10	15	2	1
31-Aug-19	188	N	B1	FW	1	F	S	1	4	3	3	4	6	18	0	0
31-Aug-19	188	N	B1	Rebar	2	S	C	1	4	3	3	4	6	18	0	0
31-Aug-19	188	N	B1	Rebar	2	F	C	1	4	3	3	4	6	18	0	0
1-Sep-19	189	N	B1	Con	1	IP	W/C	1	4	3	3	4	20	3	0	0
1-Sep-19	189	N	B1	FW	2	S	C	1	4	3	3	4	20	3	0	0

Table 3  
**Actual duration compared to the project's preplanned duration**

RCC B1 Z2	%	Start	Finish	Planned	Actual	Difference
W/C FW	100	9/1/19	9/7/19	5	6	-1
W/C REBAR	100	8/31/19	9/7/19	3	7	-4
W/C FW	100	8/31/19	9/22/19	2	22	-20
W/C CON	100	9/3/19	9/23/19	1	20	-19
W/C FW	100	9/7/19	9/25/19	2	18	-16
S FW	100	9/14/19	9/19/19	6	5	1
S/B REBAR	100	9/21/19	9/23/19	4	2	2
PT WORKS	100	9/21/19	9/25/19	3	4	-1
S REBAR	100	9/25/19	9/28/19	3	3	0
B2 S FW	100	9/26/19	9/29/19	1	3	-2
S CON	100	10/2/19	10/2/19	1	0	1
PT	100	10/6/19	10/13/19	5	7	-2

Table 4  
**Planned vs actual data**

Floor	Works	Zone	Average Planned per floor in Days	Average Actual per floor in Days	Difference in Days	Sum Planned Days	Sum Actual Days
B3	S	1	4	5	1	44	55
		2	4	6	2	44	66
B2	S	1	3	3	0	41	42
		2	3	3	0	41	42
B1	S	1	3	3	0	41	41
		2	3	7	4	41	103
GF	S	1	3	4	1	41	57
		2	3	4	1	41	55
1 <sup>st</sup>	S	1	3	3	1	41	48
		2	3	6	3	41	81
2 <sup>nd</sup>	S	1	3	4	1	41	55
		2	3	5	2	41	75

Table 5  
**Sample for the Rebar activity**

FLOOR (n)	ZONE	Activity	Element	Sum Planned Per Activity Type	Sum Actual Per Activity Type	Average Time Per Each Phase of Activity (d)	Average Time Per Each Phase of the Activity/Project	Total Average * Total Phases	Average Number Of Workers (W)	Average Workers for The Whole Zone
B3S	1	Rebar	W/C/S/B	12	6	2	2	7	15	11
B2S		Rebar	W/C/S/B	10	7	2			12	
B1S		Rebar	W/C/S/B	10	7	2			12	
GFS		Rebar	W/C/S/B	10	8	3			9	
1STS		Rebar	W/C/S/B	10	8	3			8	
2NDS		Rebar	W/C/S/B	10	8	3			7	
FLOOR (n)	ZONE	Activity	Element	Sum Planned Per Activity Type	Sum Actual Per Activity Type	Average Time Per Each Phase of Activity (d)	Average Time Per Each Phase of the Activity/Project	Total Average * Total Phases	Average Number Of Workers (W)	Average Workers for The Whole Zone
B3S	2	Rebar	W/C/S/B	12	13	4	4	12	8	9
B2S		Rebar	W/C/S/B	10	9	3			16	
B1S		Rebar	W/C/S/B	10	12	4			9	
GFS		Rebar	W/C/S/B	10	11	4			8	
1STS		Rebar	W/C/S/B	10	10	3			8	
2NDS		Rebar	W/C/S/B	10	16	5			6	

Table 6  
**Frequency count between Normal and Changes was measured after the correlation analysis**

Floor	Zone	Activity	Correlation	P-Value
B3	1	FW	0.005	0.993
B2		Rebar	-0.974	0.001
B1		PT	0.000	1.000
GF		Con	0.000	n/a
1		FW	-0.28	0.591
2		Rebar	-0.712	0.113
B3	2	Rebar	-0.712	0.113
B2		PT	-0.126	0.812
B1		Con	-0.206	0.698
GF				
1				
2				