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CHALLENGES AND RISKS RELATING TO MEP ENGINEERING IN LARGE BUILDING CONSTRUCTION PROJECTS

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MEP (mechanical, electrical, plumbing) systems are integral parts of modern buildings. Adequate conception, design, and installation of MEP systems are an essential prerequisite for a successful project. Experience has shown that the practical implementation of this aspect is often a challenge for the involved project stakeholders due to the increasing complexity of MEP systems. This raises the question of whether the field of MEP engineering is particularly sensitive to potential conflicts and disruptions in complex construction projects compared to other trades. In order to investigate these questions, a survey based on a standardized questionnaire was carried out among Austrian experts with experience in large building construction projects. Overall, 515 experts participated in this survey, with 365 completely answering the questionnaire. The results show that the participants consider proper project integration of MEP engineering as a critical success factor in complex construction projects. They also show that inadequate consideration of this aspect poses a substantial risk for project disruptions.

Keywords: Time and cost overruns, Project disruptions, MEP planning and coordination, Online survey, Stakeholder-specific analysis.

1 INTRODUCTION

Large-scale construction projects facing substantial time and cost overruns are often subject of public interest and debates. In Germany, for example, projects such as those analyzed in Kostka and Fielder (2016) led to the establishment of a high-level commission in 2013 with the aim of preparing reform proposals for the development and implementation process of large-scale construction projects. In its report (BMVI 2015), the commission calls for a new culture in such projects. The topic has also attracted interest in the scientific community. Flyvbjerg *et al.* (2003), for example, investigated the frequency and magnitude of cost overruns of transportation infrastructure projects. They conclude that cost escalation is the rule rather than the exception, that it is a global phenomenon and that the situation has not improved over the last 70 years. Iyer and Jha (2005) investigated factors affecting cost performance of Indian construction projects. They argue that coordination among project participants is the most significant factor with respect to positive influence on cost performance. According to the analysis of Sambivasan and Soon (2007), who investigated causes for time overruns in Malaysian construction projects, improper planning, poor site management, and inadequate contractor experience are the top three causes for delays.

The relevance of MEP engineering has not been studied in this context so far. For this reason, a survey was conducted in Austria in order to assess the importance of MEP in complex construction projects such as airports, hospitals, laboratory buildings etc. and to investigate causes of project disruptions associated with MEP. The results are summarized in Monsberger and Fruhwirth (2018). The aim of this study is to help managers and decision makers in large-scale building projects, who are often not MEP specialists, to recognize and assess risks associated with MEP.

2 METHODOLOGY

A standardized questionnaire containing 57 questions was compiled and sent to 1527 Austrian experts, who can be assigned to one of the following stakeholder groups: clients, architects, consultants (MEP), consultants (others), contractors (MEP), contractors (construction), facility managers and others. Stakeholder group specific evaluations were made for all questions. The questionnaire was implemented using the online tool LimeSurvey, and the software IBM SPSS Statistics version 25 was used for evaluation. The answers were analyzed by means of descriptive statistics and cross tabulation. In addition, the Kruskal-Wallis test (H test) and the SPSS built-in Dunn-Bonferroni post-hoc test were used in case of ordinal questions to evaluate differences between the stakeholder groups. Overall, 515 experts responded and 365 completed the questionnaire in full. The number of respondents is listed for each result in total and per stakeholder group. The figures and tables presented in the following are adapted from Monsberger and Fruhwirth (2018).

3 SELECTED RESULTS

Figure 1 shows an assessment of works with respect to project disruptions. About 77% of the respondents identify "MEP installations" as a domain that frequently causes disruptions in complex construction projects, followed by "interior work" (excluding MEP installations) with a score of 53%. The number of respondents considering "structural work", "earthwork," and "facade assembly" as a frequent cause of disruption is substantially smaller.

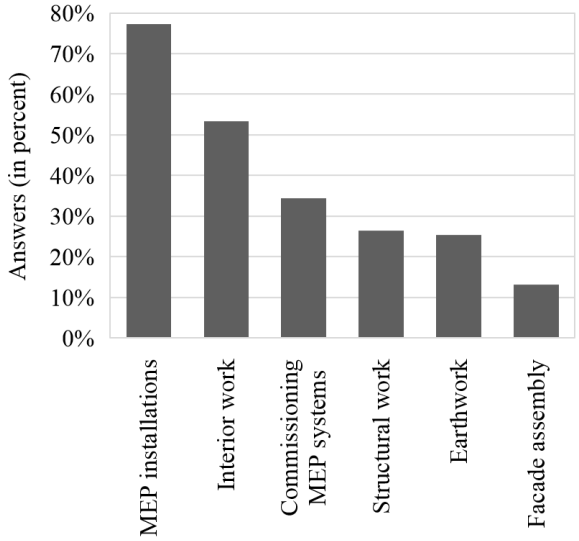

Figure 1. Works that frequently cause disruptions in complex construction projects (n=378).

Table 1 shows the stakeholder-specific result. All stakeholder groups except "MEP consultants" and "MEP contractors" consider "MEP installations" as a frequent source of project disruptions. It seems comprehensible that these groups do not see their own profession as a predominant disturbing factor in construction projects. However, even in these two groups "MEP installations" are on the second position. In case of "MEP contractors," the difference between "interior work" (73.7%) and "MEP installations" (71.1%) is as small as 2.6 percentage points.

Table 1. Works that frequently cause disruptions in complex construction projects – stakeholder-specific analysis.

	Clients	**Architects**	**Consultants (MEP)**	**Consultants (others)**	**Contractors (MEP)**	**Contractors (construction)**	**Facility managers**	**Others**
	n=82	n=32	n=84	n=40	n=38	n=45	n=34	n=23
MEP installations	79.3%	87.5%	56.0%	85.0%	71.1%	91.1%	85.3%	91.3%
Interior work	58.5%	28.1%	72.6%	50.0%	73.7%	31.1%	35.3%	43.5%
Commissioning of MEP systems	39.0%	43.8%	20.2%	47.5%	23.7%	33.3%	50.0%	30.4%
Structural work	20.7%	15.6%	36.9%	27.5%	31.6%	22.2%	17.6%	34.8%
Earthwork	30.5%	28.1%	19.0%	25.0%	7.9%	44.4%	20.6%	26.1%
Facade assembly	13.4%	18.8%	7.1%	17.5%	15.8%	15.6%	8.8%	17.4%

Moreover, participants were asked to assess MEP in terms of the client's risk for additional costs (Figure 2). The respondents consider the risk for additional costs caused by MEP comparatively high, with the majority (42.5%) of respondents rating it with 7 or 8 on a 10-point scale.

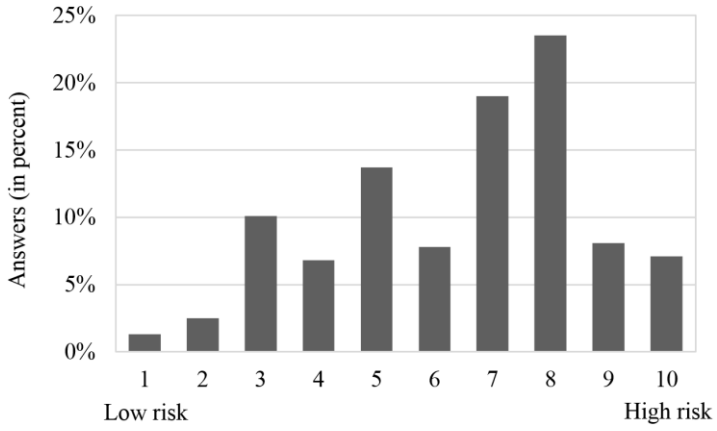

Figure 2. Assessment of the client's risk for additional costs caused by MEP (n=395).

The stakeholder-specific analysis in Table 2 reveals that the assessment of the stakeholder group 'MEP consultants' differs from the other groups. A Kruskal-Wallis test (H=47.502; p=0.000) shows that this difference is statistically significant. Pairwise comparison of the stakeholder groups via a Dunn-Bonferroni post-hoc test confirms that the answer pattern of the

group "MEP consultants" differs from all other stakeholder groups except "facility managers" with statistical significance. For the latter the calculated p-value of the post-hoc test is p=0.384 and hence above the pre-defined threshold of 0.05.

Table 2. Assessment of the client's risk for additional costs caused by MEP - stakeholder-specific analysis.

	Clients	**Architects**	**Consultants (MEP)**	**Consultants (others)**	**Contractors (MEP)**	**Contractors (construction)**	**Facility managers**	**Others**
Scale (clustered)	n=88	n=33	n=86	n=41	n=42	n=46	n=35	n=24
1 - 3	11.4%	12.1%	31.4%	2.4%	9.5%	2.2%	14.3%	12.5%
4 - 7	50.0%	33.3%	53.5%	56.1%	35.7%	43.5%	51.4%	41.7%
8 - 10	38.6%	54.5%	15.1%	41.5%	54.8%	54.3%	34.3%	45.8%

A further goal of the survey was to identify causes of project disruptions and additional costs associated with MEP. Figure 3 shows an assessment of nine different causes. Almost 70% of the respondents consider "incomplete planning when call for tender is released" as the main cause of additional costs caused by MEP, followed by "late decision making" (64.5%) and "lack of coordination between trades" (60.3%). According to this result, the factors "poor contracts" (4.7%), "regulations" (11.2%), and "lack of cooperation between contractor and subcontractors" (18.3%) are of minor significance.

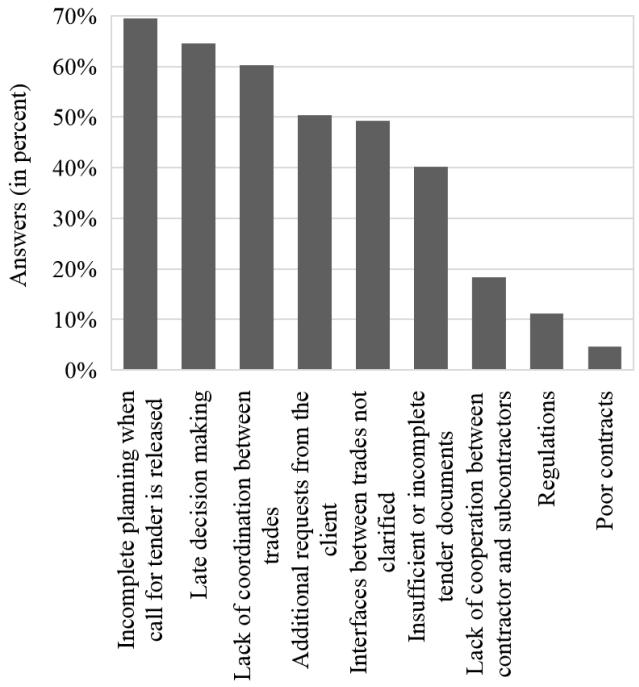

Figure 3. Causes of additional costs associated with MEP (n=383).

Table 3. Causes of additional costs associated with MEP – stakeholder-specific analysis.

	Clients	Architects	Consultants (MEP)	Consultants (others)	Contractors (MEP)	Contractors (construction)	Facility managers	Others
	n=84	n=31	n=86	n=40	n=39	n=45	n=34	n=24
Incomplete planning when call for tender is released	73.8%	64.5%	48.8%	77.5%	84.6%	88.9%	67.6%	62.5%
Late decision making	45.2%	64.5%	81.4%	65.0%	76.9%	64.4%	55.9%	62.5%
Lack of coordination between trades	73.8%	61.3%	47.7%	62.5%	53.8%	44.4%	70.6%	79.2%
Additional requests from the client	33.3%	51.6%	76.7%	50.0%	53.8%	46.7%	35.3%	37.5%
Interfaces between trades not clarified	54.8%	45.2%	37.2%	60.0%	46.2%	55.6%	52.9%	50.0%
Insufficient or incomplete tender documents	45.2%	29.0%	23.3%	30.0%	59.0%	57.8%	35.3%	58.3%
Lack of cooperation between contractor and subcontractor	19.0%	12.9%	27.9%	17.5%	5.1%	8.9%	29.4%	12.5%
Regulations	15.5%	6.5%	10.5%	12.5%	7.7%	8.9%	14.7%	8.3%
Poor contracts	2.4%	6.5%	10.5%	0.0%	5.1%	2.2%	5.9%	0.0%

The stakeholder evaluation gives an inhomogeneous picture. MEP contractors consider "late decision making" as the main reason for additional costs. "Facility managers:" and "others" see "lack of coordination between trades" as the main cause. All other stakeholder groups regard "incomplete planning when call for tender is released" as the main reason for additional costs. It should be noticed that "clients" and "architects" consider "lack of coordination between trades" and "late decision making" equally important with "incomplete planning when call for tender is released", respectively.

4 DISCUSSION

Figure 1 shows that the vast majority of respondents consider MEP as a domain that frequently causes disruptions in complex construction projects. This indicates that the field of MEP is more sensitive to project disruptions than other areas. This reasoning is supported by other results in Monsberger and Fruhwirth (2018), which show, for example, that MEP is also an area with a high potential for conflicts. Furthermore, the risk of additional costs caused by MEP is considered to be relatively high (Figure 2). The stakeholder-specific analysis in Table 2 shows that the risk assessment by the group 'MEP consultants' substantially differs from the other groups. This picture is also partially reflected in the result in Table 1, in which 'MEP consultants' chose 'MEP installations' noticeable less often than the other groups. This pattern can also be observed in other results in Monsberger and Fruhwirth (2018). This finding is particularly relevant for clients. They should take into account that consultants might downplay project risks related to MEP. Clients should therefore be aware of the importance of MEP in complex construction projects themselves and ensure a thorough project integration and coordination of MEP.

The result shown in Figure 3 and further results in Monsberger and Fruhwirth (2018) underline the importance of planning, decision-making, and coordination. These factors are

success criteria for construction projects in general. However, they are particularly important for the MEP sector. The scope and complexity of MEP systems has increased rapidly over the past decades and will continue to increase (e.g., due to the digitalization of system components and developments such as the Internet of Things). The design and implementation of MEP systems has thus become a highly multidisciplinary and interactive task with numerous interfaces between different project domains requiring increased efforts in terms of planning and coordination. Underestimation of this complexity by decision makers and project managers is a substantial source of conflicts and disturbances resulting in time and cost overruns.

5 SUMMARY AND CONCLUSIONS

This paper discusses the significance and impact of MEP engineering in complex construction projects and identifies causes of additional costs caused by MEP. The results derive from a stakeholder survey in Austria with more than 365 participants from eight different stakeholder groups. The findings are useful for project managers and decision makers, as they can use them to make their own assessment of the relevance of MEP in a project and the risks involved. The stakeholder-specific analysis gives insight into how different project participants assess risks associated with MEP and corresponding factors causing cost overruns. Such analyses can help project managers to identify and understand differing viewpoints of stakeholder groups and to take measures to create consistent views between the client, consultants, and contractors, which is vital for project success. According to the results, project managers and decision makers should recognize that MEP engineering has become a success critical factor in complex building projects and ensure that adequate expertise and resources are available in both, management and technical project domains across all stakeholder groups. In addition, they should give MEP planning and coordination a high priority and make sure that decisions regarding MEP are adequately taken. The presented results particularly apply to the situation in Austria. They may also apply to countries where the construction sector is comparable to that in Austria (e.g., Germany). However, the increasing complexity and relevance of MEP in construction projects must be taken into account whenever modern buildings are built today.

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