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MECHANICAL, ELECTRICAL AND PLUMBING COORDINATION PRACTICES: CASE FINNISH CONSTRUCTION MARKET

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ABSTRACT

MEP (Mechanical, Electrical, and Plumbing) coordination is a challenging task in construction projects. Failing to properly manage the MEP activities can lead to consuming up to 60% of the total budget, as noted in literature. Previous studies have documented several challenges of MEP coordination; however, they did not focus on understanding different stakeholders' perspectives. Thus, in this research, we have analyzed the challenges of MEP coordination from different stakeholders' perspectives taking the Finnish construction sector as a case. The study employed semi-structured interviews, web-based surveys, and experts' workshops as means of data collection. In addition, we have also analyzed current practices for MEP coordination and presented possible ways to improve the MEP coordination in Finnish construction industries. The results showed significant shortcomings including non-accurate initial design plans, lack of trust between parties, unforeseen MEP cost at early phases, and unavailability of real-time progress monitoring tools. As a contribution, this study presented several challenges, especially in the regional context. Furthermore, this study also analyzed currently used MEP coordination practices in the Finnish construction market and presented suggestions for improvements. The findings of this study will help in the reduction of construction wastes, delays, and cost overruns in construction projects.

KEYWORDS

MEP coordination, challenges, solutions, lean tools

INTRODUCTION

The design and execution of MEP (Mechanical, Electrical and Plumbing) systems, that provide all functionality services to a building, is a challenging endeavour in construction projects. At the definition level, the mechanical systems cover up the heating, the ventilation, and air conditioning (HVAC). The electrical systems mainly include power distributions, smoke and fire alarms, security system, and lighting, and the plumbing system that deals with water supply and wastewater collection (Korman and Tatum, 2001).

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The MEP system is responsible for the building's function that assures the comfort, safety and security of the occupants. During the construction period, they have to be installed in limited spaces and are required to meet constructability, operability and maintainability criteria which create more challenges to the coordination with various other systems in the buildings (Yung et al., 2014; Lavikka et al., 2021). For this reason, several previous studies have considered MEP coordination as one of the grey areas that affect the overall success/performance of building projects (Korman et al., 2003; Tatum and Korman,2000).

The MEP system installation cost may range from 15-60 per cent of the total building project cost depending on the complexity and size of the project (Hassanain et al., 2018). Time wise, installing the MEP systems may use up to 50% of the total duration of the project (Singh et al., 2018). Thus, the implementation of an appropriate MEP coordination system is necessary for the successful completion of the project. The poor coordination system may result in delays, demolition, rework and affects the operation and maintenance phase of the building project (Wan and Kumaraswamy, 2012; Khanazode, 2010).

A significant number of studies have been carried out on MEP coordination. Some studies propose different methods to improve coordination, e.g., virtual design and construction (VDC) (Khaanazode, 2010), building information modeling (Yung et al., 2014) and Mohamad et al., 2014 who suggested modularization and standardization of MEP systems to improve construction performance. Some other studies investigated factors affecting MEP coordination (Hassanain et al., 2018; Jha and Mishra 2007; Alaloul et al., 2016), while the study by Hassanain et al., (2018) presented 36 factors affecting the MEP coordination where the complexity of the project, the experience of the design team and the quality of where top in the list.

The fact that MEP works involves several stakeholders from different trades and contract sides (e.g. main contractor, sub-contractors, designers, project owner, and final customers) complicates the planning, coordination, execution and control of related activities. Even though previous studies have analyzed the MEP works' challenges, they did not fully address different stakeholders' perspectives. For this reason, this research aims to examine the MEP coordination challenges from multiple project parties in the Finnish construction industry. More specifically, this research aims at answering the following questions:

RQ1: What are the key challenges and contradictions in coordinating MEP systems from multiple project parties' perspectives?

RQ2: How stakeholders could make MEP coordination more efficient?

THEORETICAL BACKGROUND

This section reviews the previous studies conducted to investigate different factors that affect MEP coordination in construction projects, mainly focusing on buildings' projects.

MEP COORDINATION PRACTICES: PROBLEMS AND SOLUTIONS

Many parties are involved in MEP coordination process from contractors to owner representatives. All participants have their own interests. For example, general contractor is more concerned about meeting contractual quality and schedule, the owner might have more focus on best quality, budget and schedule. Thus, it is expected that several conflicts

can arise among them as every party is focusing on their own objectives not the overall comprehensive project value.

Some studies have been conducted to investigate the factors affecting the MEP coordination processes in construction projects (e.g., Hassanain et al., 2018; Alaloul et al., 2016; Jha and Mishra, 2007). These studies mostly emphasized the complexity of building systems, limited budget, installation schedule and limited building space as the major challenging factors for the MEP coordination. Table 1 presents the major problems mostly cited in the literatures.

Table 1. MEP coordination problems mostly cited in literature

Problems	Explanations	References
Hurried schedules	Construction companies involved in several projects at the same time are usually characterized by hurried schedules and overload for professionals	Hassanain et al., 2018
Low budget for the project	While recruiting professionals for the construction project cost is a major determining factor. Experience and skills of the professional matters much while implementing the project.	Pennanen et al., 2011
Unclear architectural plans	Sometimes needs and requirements of the client are difficult to understand, and it may lead to challenges while creating a clear architectural plan	Hassanain et al., 2018
The design complexity of the MEP systems	While aligning MEP system into the structural system of the building several challenges need to be considered including MEP component route, component location and equipment requirements.	Lee et al., 2015
Increase in safety requirements	The recent trend of constructing complex buildings, such as high-rise buildings, has increased the safety requirements. Such as distribution of electrical energy, communication, water, waste disposal and safety of users	Korman et al., 2010
Inadequate space allocated	MEP installers are usually required to install MEP system	Korman et al., 2003
Owner's unclear requirements	Sometime owners are unclear about their needs. Their requirements can change in the later phase of the project.	Korman et al., 2003
Communication skills of the design team members	Effective communication skills is necessary while delivering and sharing of information during coordination.	Hassanain et al., 2018

The project delivery system adopted for the building project	Recent Integrated Project Delivery are more efficient as it allows involvement of all stakeholders during the life cycle of projects and thus improves the coordination process	Hassanain et al., 2018

To resolve the MEP coordination problems, previous studies have presented several practices. Majority of the approaches are focused on pre-installation phases–mostly, they suggest improvement using BIM (Building Information Modelling) tools. Major approaches discussed in the literature are presented in table 2.

Table 2. MEP coordination practices

Practices	**Explanation**	**Sources**
BIM with laser scaning	Automated geometric quality inspection using 3D laser scanning	Guo et al., 2020
Clash analysis framework	The framework provides a formal process for clash management and reuse of the knowledge.	Wang and Leite, 2016
Intra-inter teamwork concept	Partnering concept for interdependent work phases of trade and across interdependent MEP trades	Wan et al., 2012
Sequential coordination strategy	The coordination process in sequence resulted three times faster than the parallel coordination process.	Lee et al., 2014
Heuristic Reasoning	Helps to determine and resolve coordination conflicts by abstracting measurable data and relating it to a predefined potential problem.	Korman et al., 2003
BIM-based approach to automate the MEP coordination	MEP rule-based automated engine also called Autoroute is using Revit Application Programming Interface (API) tool.	Lu and Wong, 2019
Framework for BIM-based MEP layout design and constructability	This framework provides process for integrating the MEP layout from preliminary design to construction stage	Wang et al., 2016

METHOD

The overall approach to conducting this research is presented in figure 1. The literature review was conducted to create an overall picture of the topic. While reviewing the literature, we emphasized on lysing the factors that affect the MEP coordination, challenges, and solutions to improve the MEP coordination.

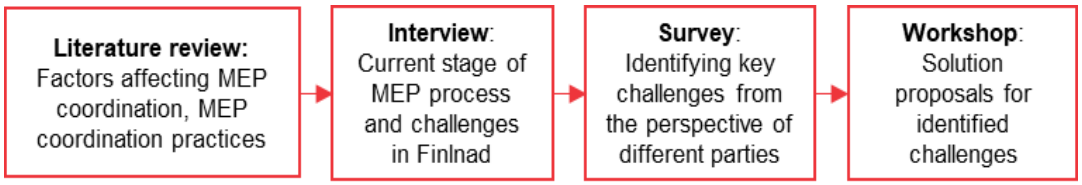

Figure 1. Research framework of the study

According to Dumas and Salzman (2006), the semi-structured interview is the best method of getting detailed or voluminous information. So, in this research, we interviewed: 3 MEP designers, 2 structural designers, 3 main contractors, 1 MEP specialist, 4 MEP contractors and 3 installers. The interviewee had experiences from different kinds of projects, e.g. hospitals, schools and housing projects. The semi-structure theme mainly focused on currently adopted MEP coordination practices in Finland, MEP coordination challenges and possible solutions.

Based on the interviewees' responses, a web-based survey was conducted to find out how significant the challenges discussed during the interviews are. For this, we have sent survey forms to various MEP stakeholders. In total, we have received 384 responses.

An expert workshop was conducted to discuss in detail about challenges with the current MEP coordination practices which were identified in interviews and surveys. A total of 41 experts participated in the workshop and they suggested several recommendations to improve the MEP coordination practices in Finland.

RESULTS AND ANALYSIS

A semi-structured interview with various MEP stakeholders was conducted. Themes of interview questionnaire were mostly focused to identify the current situation of MEP in the Finnish construction market. Table 3 presents the views of several stakeholders regarding the Finnish construction industry.

Table 3. Stakeholders' views of MEP coordination in Finland

MEP stakeholders	Positive factors	Challenges/ Factors to be improved
MEP consultant/design office	Adoption of alliance model: it makes actors think about common goals, implementation of prefabrication elements, utilization of software	Skilled designer is needed, too much additional work for MEP contractors, Involvement of MEP contractors in design phase, schedule management program could be developed, prefabrication should be decided in early phase, bonus could be provided if task is completed beforehand, BIM does not have a design standard that could be used for maintenance.

MEP contractors	Contractors are involved in the design, regular MEP contractors' meetings	Biding shouldn't focus only on the price, more time is necessary for the planning, collecting agreement shouldn't guide design choices, test period is too short,
Main contractor	Implementation of prefabrication is increasing, big rooms, last planner system, congrid software are being used	The contractor should be involved at an early stage. Alliance model should be developed- price shouldn't be the only factor to be considered, People have not much experience with prefabrication, partners should be consulted in scheduling, additional and modification work is employment and should be reported early, the flow of information from real-time site should be developed,
Structural designer	Involvement of contractor in the design stage,	Younger designers cannot read the drawings but can only study the model, regular meeting with MEP designer is needed, better alignment of MEP design to structural design is needed.
MEP designer	Adoption of TVD process: the operating model is coordinated together, implementation of last planner system	Collective agreements should not control design options, preliminary plan should be improved, the method should be developed to get accurate initial data

All the interviewed MEP stakeholders were positive about the practice of the alliance model where all the project parties will share the risks and rewards of the project. Also, some reviewers mentioned that the involvement of the MEP contractors in the planning phase is a positive change. Other factors such as the implementation of lean approaches, such as prefabrication, last planner system and Target Value Design (TVD) process were the positive factors in the Finnish construction market. On the other hand, interviewees mentioned several factors that could be improved. For instance, improvement of schedule management program, collective agreement that restricts the innovation, skills of the worker and involvement of contractor in an early phase.

To get deeper insights into more factors during the semi-structured interviews, we conducted a web-based survey with the same theme as it was used in the interview. The survey collected views from respondents on multiple-choice questions, and in addition, each section included an open-ended question for comments and clarification. We received responses from 384 experts. Most of the respondents had worked in the construction industry for over 15 years. After analyzing the survey responses expert interview responses, the major challenges and the currently used practices in the Finnish construction market are presented in table 4.

Table 4. Challenges and current practices of MEP coordination in Finnish construction market

Challenges	Current practices
❑ Shorter project schedule	❑ LPS
❑ Innovation restrictive collective agreement	❑ Big rooms
❑ Over workload for designers	❑ Congrid: Construction solutions
❑ People to people communication during installation	❑ Implementation of prefabricated products
❑ Availability of real time progress simulation software	❑ BIM
❑ Determination of MEP cost at the beginning	❑ Kotopro: A documentation tool
❑ Less accurate initial plan/design	❑ Teams for meeting
❑ Lack of trust between parties	❑ Scrum thinking
❑ Lower budget for the design	
❑ MRL-maa rakennus laki (Land utilization act)	❑ A system dynamic model

Majority of the identified challenges in the Finnish construction sector were similar to previously identified challenges in other geographical locations. However, some challenges were new or unique. For instance, some provisions of the Land Utilization Act were unique in the Finnish context, as it dealt with the physical, chemical, and microbial condition of the building. Also, availability of real time progress simulation software, and unforeseen MEP cost at early phases were identified in the Finnish construction sector.

After analyzing the current practices and challenges, an expert workshop was organized to produce concrete development suggestions for MEP stakeholders. Overall, the workshop suggested nine recommendations. These could be classified into three categories: Project planning phase, MEP design phase, and production planning and control phase. There are presented in table 5.

Table 5. MEP coordination improvement suggestions for stakeholders

Project planning	MEP design	Production planning and control

1. More detailed analysis of MEP installation skills during project development stage	4. Planning and adapting the planning schedule to other project tasks	7. Involvement of the MEP Contractor in site scheduling
2. Emphasis on quality, competence and project objectives in the procurement of MEP contracting	5. Differentiation of design for procurement and implementation as needed	8. Better methods for assessing and communicating the wide-ranging effects of change
3. More balanced and transparent MEP contractor selection	6. Increase in implementation of prefabrication	9. Employee-driven digital applications for change management and scheduling

DISCUSSION

Some previous studies have also analysed the MEP coordination problems in construction projects in different geographical locations (e.g., Hannanain et al., 2018; Alaloul et al., 2016; Monsberger & Fruhwirth, 2018). Most of the challenges in the Finnish construction market identified in this research were the same as previous researcher has identified, such as long project schedules, work overload for designers and lack of sufficient skills of MEP installers. However, some challenging factors identified in this research, such as, land acquisition act, unavailability of real time progress monitoring tools and unavailability of accurate MEP cost estimation tools especially in the high buildings were not indicated in the previous studies.

To improve the MEP coordination system, several approaches are presented in previous studies (e.g., Mohamad et al., 2014; Wang et al., 2016; Guo et al., 2020). They mostly emphasised in the pre-installation phase, such as, BIM based approach to automate the MEP coordination, BIM with laser scanning and clash analysis tool in BIM modelling. Very little attention has been given for installation phase. In Finnish construction market BIM with all updated tools are implemented. In addition, to improve MEP coordination during the installation phase, several lean tools are applied such as, big room, LPS and prefabricated products.

However, currently adopted methods were not sufficient to resolve all the MEP coordination related problems. To analyse the causes of problems and make recommendations for improvements, we organised the expert workshop. Based on the workshop the major causes of MEP coordination could be categorised to: (a) Changes in plan during implementation (b) lack or late decision making on MEP services, and (c) Insufficient coordination between the implementation and procurement of MEP systems. Also, workshop made several recommendations for stakeholders to improve the MEP coordination which could be divided into three categories: 1) increasing stakeholders' cooperation, 2) changing processes and practices, and 3) utilizing technologies and product development.

CONCLUSION

The aim of this study was to identify the major challenges and contradiction of MEP coordination in Finnish construction market, analyse currently adopted solutions and present suggestions for further improvement.

The major challenges of MEP coordination in the Finnish construction sector were, among others, a certain level of confusion caused by the Land Utilization Act, unavailability of real time progress simulation software, and unforeseen MEP costs at early phases of construction projects. For instance, the Land Utilization Act was unique in the Finnish context, as it dealt with the physical, chemical, and microbial condition of the building, and its thorough implementation was considered a challenge, at least initially. The availability of real time progress simulation software and its accuracy were also issues of concern. Similarly, unexpected MEP costs also put financial burden on construction projects. Our study shows that to avoid these challenges, stakeholders needed to improve the inter-intra cooperation, needed to change the process and practices and implementation of new technologies and product development.

Several respondents in this research indicated the lack of real time work progress tracking tools, so further research could investigate the development of this reality capture technologies. Also, it is discussed that prefabrication is being implemented in a slow progress in the Finnish construction market, and previous studies have not given enough attention to identify the benefits of prefabrication connection with the MEP coordination. So, future research could analyse the impact of prefabrication for better MEP coordination system. As a limitation, this this study highlighted the challenges of the whole construction sector but did not analyse challenges considering from the building types or HVAC system. Future research could further investigate the MEP coordination challenges based on different building categories, e.g., hotel projects, hospitals and schools.

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