A Review on Coordination of MEP Systems in Construction Industry

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Abstract — Construction industry is a key driver of development as it means to the fulfilment of various requirements up to a desired extent of satisfaction. Mechanical, Electrical and Plumbing (MEP) systems are basic utilities of any building. Hence, they must be coordinated with each other to improve their productivity. MEP Coordination is a process of connecting each element of system without any interruption such that it can be functioned satisfactorily up to its desired level. Basically, MEP Coordination is highly impacted by the nature of work. As scale of project increases, MEP systems become more complexed as their design criteria has been changed. Accordingly, the effectiveness of MEP Coordination is gradually affected. Hence, to achieve critical design criteria and functionality, identify the diversified factors influenced by MEP Coordination at planning and scheduling stages in construction industry which is the desired objective of this review.

Keywords — Construction project, Coordination, MEP, Planning, Scheduling

I. INTRODUCTION

In the present scenario, construction industry is globally fragmented as it plays an important role to hike an economy of developing countries. Construction industry has been implemented in tremendous way as the scale and complexity differs along with project. To chase the complexity, more design efforts have been put for successfully completion of project on time, on budget and with its best quality. [4]

For execution of construction project, many stakeholders are involved in one project such as civil engineers, project managers, architects, contractors, consultants etc. [6] They work together at one platform for performing various construction activities which come under their scope.

Mechanical, Electrical and Plumbing (MEP) systems which is simply known as active building systems. In particular, Mechanical, Electrical and Plumbing systems need to be more attention as it is to be more difficult to coordinate each of them. [1] For any project, poor coordination among MEP systems leads to requirement of more efforts to execute a work appropriately. Hence, Coordination among MEP systems is proven to be one of the grey areas of research. Various factors are responsible for MEP Coordination. Hence, it is more fruitful to diagnose factors at beginning stages of construction i.e. during planning and scheduling stages.

II. MEP COORDINATION

Mechanical, Electrical and Plumbing (MEP) systems' coordination is basically referred as correlation of active building systems which routed connected elements of each system in such a way that it must fit into the architectural and structural envelope in order to achieve functionality of building. [11] MEP Coordination is associated with integration of various elements of each system which resulted into tempering the building environment, distribution of electric energy, allowing communication among participants, providing water and dispose of waste. It also referred as the process of managing interdependencies among each building system to improve effectiveness of MEP systems. [9]

MEP Coordination involves defining the locations for components of building systems in order to avoid interferences within congested spaces. Coordination of building systems is a multidisciplinary effort of providing opportunity to integrate the knowledge related to each building system and optimize the functional performance of a system in order to reduce the level of difficulty. [2] Coordination among various components of each building system directed towards the fulfilment of the unidentified and non-prioritized objectives that affects performance criteria and realizing the roles and responsibilities of participants to support project optimization.

 DOI : 10.18231/2454-9150.2019.0142

III. IMPORTANCE OF MEP COORDINATION

MEP Coordination is referred as most economical arrangement which resulted into avoiding rework, minimizing field conflicts between building service system, achieving the design criteria and improving the overall performance. [5] Coordination of MEP systems become more effective by providing opportunity in order to structure and integrate the knowledge related to each building service system. Through Coordination of MEP systems, discussion about construction scheduling and installation sequences may take place to comply with the several types of criteria and to develop objective hierarchy. Effective MEP Coordination leads to identify the possibility of problems occurrence prior to field work that promoting minimization of wastage of material resources. MEP systems' coordination provides valuable perspective to get the best possible solution within the budget limitations that meets the owner's needs. Hence, MEP Coordination possesses great importance as it is only link in the chain of coordination events. For make MEP Coordination more effective, several kinds of studies were carried out. To identify its likelihood of occurrence and its importance, Relative Importance Index (RII) and Important Index (IMPI) techniques are used and based on that the most effective factors affecting MEP Coordination can be identified.

IV. PARTICIPANTS INVOLVED IN MEP COORDINATION

For accomplishment of building service systems, many participants are involved in it. It is essential that they coordinate with each other before commencement of project which resulted into better performance of each building service system. During the time of execution, they done kick-off meeting at regular interval of time to enhance productivity, to make MEP Coordination more adequate and to achieve full system functionality without compromising its quality criteria.

To attend desired objectives of any project, various participants are involved in MEP Coordination are as follows:

1. MEP Consultant
2. General Contractor
3. Facility Manager
4. Project Manager
5. Civil Engineer
6. Architect

To achieve critical design criteria and to improve performance specification, it is vital that each participant involved in project must be aware with his responsibility. Every participant has their own scope of work, role and responsibilities towards MEP systems which described as follows:

Table−1 Role of Participants involved in MEP Coordination

Participant	Role of Participant
MEP Consultant	To assure functionality of building service system after installation and coordinate each system with energy efficient solution.
General Contractor	To focus on project schedule and avoiding delays during pre-construction stage and after installation.
Facility Manager	To make sure that building service systems meet the needs of client.
Project Manager	To add value in building services by providing alternative solution of definite problems.
Civil Engineer	To assure that fabrication should be done according to specification with satisfaction of quality design criteria.
Architect	To design building service systems with least amount of resources and without affecting aesthetic view of building.

V. NEED AND OBJECTIVE OF REVIEW

Now-a-days, there are more emphasize on sustainability to improve the basic functional requirements such as aesthetics, efficiency, economy, comfort and safety which have a great consequence on Mechanical, Electrical and Plumbing (MEP) systems. MEP Coordination is basically multidisciplinary effort which is time consuming and expensive that required knowledge regarding each system. Lack of knowledge regarding coordination of each building service system may lead to wastage of financial and material resources. Coordinating interdependencies between each building system is a vital challenge to manage complexity of building service projects. The consequence of poor coordination influences the performance of MEP systems, buildability as well as project progress within schedule and budget. The objectives of review are as follows:

- To integrate knowledge regarding building services' coordination to improve overall performance of Mechanical, Electrical and Plumbing (MEP) systems.
- To aware participants with their role and responsibilities regarding MEP Coordination.
- To identify the factors significantly affects the process of coordination of MEP systems during planning and scheduling stages.

 DOI : 10.18231/2454-9150.2019.0142

- To improve systems' functionality through coordination of each building service system.

VI. PAST STUDIES

M. Wasi Baig et. Al. have discussed the overview of Mechanical, Electrical and Plumbing (MEP) system and its entrepreneur approach towards our country. Role and responsibilities of MEP engineer and symbols used in MEP drawings have been also explained. The experience as MEP engineer should include involvement with mechanical, electrical and/or plumbing system design and analysis for large commercial or governmental building projects organizational management of mechanical, electrical or plumbing systems in facilities or construction. [8]

Mohammad A. Hassanain et. Al. have reviewed literature in the domain of building services' coordination to identify the factors with great influence during the design development and review stages. Interviews were conducted to ensure the comprehensiveness, clarity and validity of the factors identified. A questionnaire survey was developed to determine the importance index of the identified factors. Further, the questionnaire survey responses were analyzed, factors were ranked based on their level of importance and the level of agreement among various groups of professionals was determined. The top five factors include the scale and complexity of the project, the level of experience of the design team, the quality of the preliminary/conceptual design of the building project, the clarity of the requirements and objectives provided by the owner, the allotted budget for the project and communication skills of the design team members. [7]

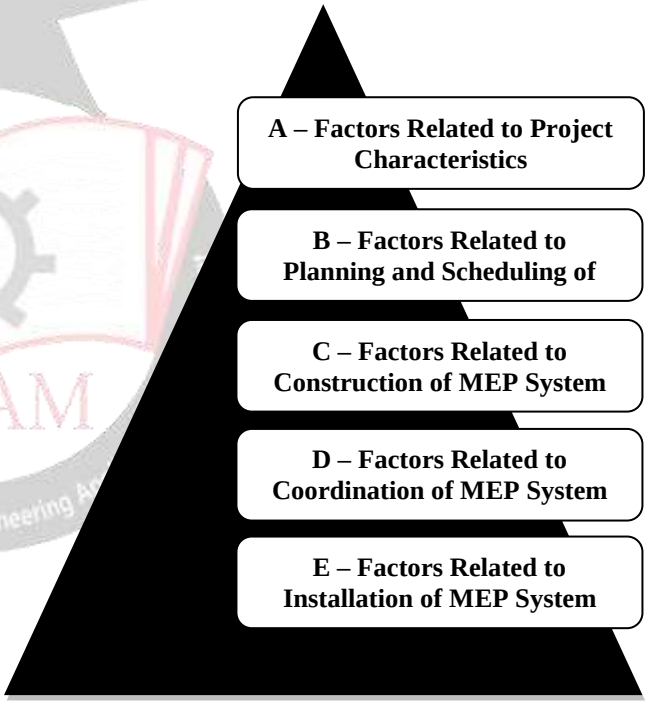
Darshit R. Shah and Dixit N. Patel have been described the study and identification of factors affecting scheduling of multiple projects in Indian construction industry. The architects, contractors and developers of various Vadodara and of various cities of Gujarat who work in Vadodara were targeted for survey. The analysis of these questionnaires can be done through calculation of Relative Importance Index (RII) and Importance Index (IMPI) of each clause. As per results generated by RII and IMPI, there are top 15 factors are more critical to scheduling of multiple projects. Among them top 3 critical factors are: Poor site management and supervision, Commitment of the project participants and Ineffective project planning and scheduling. [3]

Thomas M. Korman has been recommended a process for performing MEP Coordination and described how rules and guidelines can improve the MEP Coordination process in buildings using BIM software. The current conditions in the design and construction industry drive current practice for MEP Coordination and create an opportunity to improve it. From the discussion the problem relevant to current practice has been identified and according to problem, the procedure was recommended for performing MEP Coordination using BIM software. [10]

VII. IDENTIFICATION OF FACTORS

During planning and scheduling stages in construction industry, it is essential to plan each activities and tasks to be performed as per its time of execution. For Mechanical, Plumbing and Plumbing (MEP) system, the sequence of installation of each element of building system within the allocated space has been decided before commencement of project. After installation systems will be functioned appropriately with better performance through MEP Coordination.

To achieve critical quality design criteria for building systems, various factors affecting MEP Coordination must be identified during planning and scheduling stages of construction projects. Further, different factors which have a great consequence on MEP Coordination have been characterized into five major group as per follows:



Figure–1 Categories of Factors

Each group has its own characteristics and reliability which plays an important role to coordinate each building system effectively. Further, each major group has been categorized into its subfactors which have a great consequence on MEP Coordination during planning and scheduling stages in construction industry.

Hence, as per outcome total 32 factors have been identified after categorization which are taken into account at beginning stage of construction project i.e. during planning and scheduling stages. A list of classified factors according to their group characteristics has been given as follows:

 DOI : 10.18231/2454-9150.2019.0142

Table−2 List of Factors

Sr. No.	Factors
A – Factors Related to Project Characteristics	
A1	Scale and complexity of project
A2	Location of project
A3	Type and Nature of project
A4	Undefined Scope of project
A5	Sustainability
B – Factors Related to Planning and Scheduling of Project	
B1	Schedule of project
B2	Plan to deliver a project
B3	Allocated budget for project
B4	Quality level of project
B5	Time constraint of project
B6	Project performance
B7	Information & Details of project
B8	Task dependencies
B9	Overall Specification
B10	Kick-off meeting
B11	MEP drawings documentation
C – Factors Related to Construction of MEP System	
C1	Fabrication & Clearance of MEP system
C2	Allocated time for fabrication
C3	Lead time of component of MEP system
C4	Expandability & Retrofit for each component
C5	Insulation of component
D – Factors Related to Co-ordination of MEP System	
D1	Coordination ability of participants
D2	Commitment of all parties to the project
D3	Decision making ability of participants
D4	Conflicts among participants
D5	Monitoring of critical path analysis
D6	Fit into architectural & structural envelope
E – Factors Related to Installation of MEP System	
E1	Space allocation for installation of MEP system
E2	Installation sequence of MEP system
E3	Uses of connection supports during installation of MEP system
E4	Monitoring of MEP components during installation of MEP system
E5	Safety consideration during installation of MEP system

Description the above listed factors is described as below:

1 – Scale and complexity of project: The amount of design effort required increases along with the size of project which resulting into difficulties and complexity in MEP coordination.

2 – Location of project: Site condition differs along with the project that influences design elements, structural components and type of design and installation used. Location of project also constitutes the professional composition of various disciplines of coordination team.

3 – Type and Nature of project: According to type and nature of project, the critical design criteria, functional requirements, interactions, complexity and coordination of MEP system differ. Type and nature of projects are decided based on the function of building such as residential, commercial, industrial, institutional etc.

4 – Undefined scope of project: Scope of project involves determining and documenting a list of project goals, features, tasks to be performed. If scope is not clearly defined then the criteria to be achieved and the work that must be done to deliver a project will not be performed effectively.

5 – Sustainability: The project associated with MEP Coordination is mainly focused on satisfying the building system needs of today while anticipating the needs of the future with sustainable, high performance and energy efficient solutions which provide a superior environmental climate, the highest level of energy efficiency and an optimized economy of operation.

6 – Schedule of project: The schedule of project is relevant to prepare and update timeframe of which organizational resources will be allocated to deliver a project on time by preparing milestone charts.

7 – Plan to deliver a project: To deliver a project, we have to use or write a briefing of project execution approaches, such plans cover activities delivered by the different participants.

8 – Allocated budget for project: Cost is a key determining factor which has a significant influence on the type of specifications and elements adopted for the building design.

9 – Quality level of project: A quality management process is introduced in a project towards Quality planning, Quality assurance and Quality control. Quality assurance plan is prepared for the project in line with contract specification.

10 – Time constraint of project: Time constraint is associated with how long the various tasks and resources are tackled by different expertise. It is hitting the deadline and delivering as planned.

11 – Project performance: The unexpected cost overruns and schedule delays have given rise to the need for processes to measure project performance.

12 – Information & Details of project: Identifying and gathering information and details based on all parties' requirements and consolidation to be used in planning and scheduling before the project commencement.

 DOI : 10.18231/2454-9150.2019.0142

13 – Task dependencies: Identifying task dependencies using PERT or CPM network analysis to facilitate the planning and scheduling of various tasks to be performed.

14 – Overall Specification: A specification contains objective determination, resource use, information, active system services, user interface and quality requirements. It ensures to meet the defined standards of project.

15 – Kick-off meeting: It involves arrangement of all gathered information and details with all parties before commencement of project in order to clarify and review scheduled of milestones for their area of activities.

16 – MEP drawings documentation: MEP drawings documentation comprises of a comprehensive set of sequential drawings in the order of their occurrence during the time of installation of system. They are a roadmap utilized by project managers and installers which greatly affect the profitability of any project.

17 – Fabrication & Clearance of MEP system: Fabrication of MEP system determines how various components of each building system will be installed in definite spaces which have a great influence on MEP Coordination. Hence, the required clearance for MEP systems is a key factor considered to install the components in their known sequence.

18 – Allocated time for fabrication: The time considered for fabrication influence selection of building systems, delivery time of elements of system and fabrication schedule.

19 – Lead time of component of MEP system: Lead time typically refers to the amount of time that elapses between placing and order for an element and its delivery to site. It designates average lead time for construction of each component.

20 – Expandability & Retrofit for each component: Expandability & Retrofit requirements for particular component of MEP system should be taken into account during construction of MEP system in order to improve energy efficiency, increase productivity, reduce maintenance cost and improve comfort & safety.

21 – Insulation of component: It designates insulation type and thickness of particular component of MEP system which helps each component in order to fit into definite space during the time of installation.

22 – Coordination ability of participants: By coordination, all participants organize each component and bringing them together and integrate it into one system which allowed the whole project to move forward on-time and on-budget.

23 – Commitment of all parties to the project: Commitment of all parties to the project refers to the willingness of the project participants towards a pooled effort for achieving a required performance criterion.

24 – Decision making ability of participants: Effective decision making involves the ability of participants to negotiate which influence MEP coordination process.

25 – Conflicts among participants: The conflict among project participants leads to impair the team spirit, leads to division among the team, lack of cooperation between the conflicting groups, tends to cause progress of work.

26 – Monitoring of critical path analysis: Regular monitoring of critical path activities for adhering to schedule is most essential part of coordination of MEP system.

27 – Fit into architectural & structural envelope: Mechanical, Electrical and Plumbing (MEP) systems is basically referred as active building systems which routed connected elements of each system in such a way that it must fit into the architectural and structural envelope for effective coordination.

28 – Space allocation for installation of MEP system: The space allocated for installation of MEP systems is key impactor for building services' coordination. Inadequate spaces could impair the installation of building system.

29 – Installation sequence of MEP system: The installation sequence of MEP systems determines the priority of installation and thus influences the MEP coordination process. To maximize the efficiency of coordination, the typical installation process for MEP systems should be considered and prioritized.

30 – Uses of connection supports during installation of MEP system: The connection supports used during the installation of MEP systems may include pipe racks or trapeze hangers used for holding electrical conduit pipes to the wall. These support systems influence the ease of routing through architectural and structural elements.

31 – Monitoring of MEP components during installation of MEP system: It refers as to observe and check the progress of installation of MEP systems over a period of time in order to keep under systematic review.

32 – Safety consideration during installation of MEP system: The increasing complexity of MEP systems results in a corresponding increase in the scope of safety requirements during the coordination processes for the distribution of electrical energy, communication, provision of water, waste disposal and safety of users.

VIII. CONCLUSION

The integrated knowledge regarding Mechanical, Electrical and Plumbing (MEP) systems can be fruitfully applicable to improve overall performance and to achieve critical design

 DOI : 10.18231/2454-9150.2019.0142

criteria with full system functionality. This knowledge is helpful to all participants involved in project for creating awareness of their roles and responsibilities of completion of project successfully through MEP coordination. To complete the project on-time and on-budget, it is advisable to diagnose various factors which have a great consequence on MEP Coordination. Based on past studies an identification of factors affecting MEP Coordination has been done. After referring various literatures, the most critical factors which affects Coordination of MEP systems are: Scale and complexity of project, Allocated budget for project, Quality level of project, MEP drawings documentation, Commitment of all parties to the project, Conflicts among participants, Monitoring of critical path analysis.

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 DOI : 10.18231/2454-9150.2019.0142