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IMPLEMENTATION OF CONSTRUCTABILITY AT VARIOUS PHASES IN CONSTRUCTION PROJECT

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Abstract

The construction business is a fundamental supporter of the process of improvement, as it impacts the others areas of economy. In most emerging nations like India, further developing countries limit and capacities is significant, including working on the proficiency and nature of development works. Considering issues in various phases of the undertaking upgrades limits that forestall abilities of contractors to participate in further developing project performance. Primavera and DSM have been established as effective tools for planning activity sequences and managing information transfers. The goal of this work is to use these techniques with constructability knowledge to smooth out the project's complex scheduling and interdependencies during construction process. A case study on residential building was formed and the difference in completion time with and without using constructability were compared. The results showed an overall reduction of duration compared to what was initially scheduled. The results of this study will contribute to the improving efficiency in the of residential building construction.

Keywords: Constructability, Primavera, DSM, Design Structure Matrix

1 INTRODUCTION

The Construction Industry Institute (CII), defines constructability as ‘‘the optimum use of construction knowledge and experience in planning, engineering, procurement and field operations to achieve overall objectives’’ (Haggard 1986).

Constructability, for more than a decade is being used as a concept in the construction industry. Many construction sector projects have shown their substantial benefits after execution. The Construction Management Committee of ASCE Construction Division (1991) defines constructability as “the application of a disciplined, systematic optimization of the construction-related aspects of a project during the planning, design, procurement, construction, test and start-up phases by knowledgeable, experienced construction personnel who are part of a project team” (Sheehan 1992).

It is a traditional practice for designers to depend on generally rules of thumb during early design phase of projects without analyzing construction prerequisites for making crucial selections on the layouts, elements of their design and construction system (Zolfagharian and Irizarry 2017). (Felix T. Uhlik and Georgina V. Lores 1998) cited factors such as selecting great materials, fast paced technology and science, diverse codes, regulations and standards and formal training for various professionals which gave rise to complex planning, design and construction of projects.

The objective of this study is to use constructability knowledge to smooth out the project's complex scheduling and interdependencies during entire construction process. A case study on

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residential building project was formed and the difference in completion time at different phases with and without using constructability were compared.

2 SURVEY OF THE LITERATURE

Lack of integration between construction and design was one of the underlying causes of the construction industry's complex challenges as presented by English and American construction industry after a thorough evaluation. Thus, constructability became a need due to the results of this study (Emmerson 1962).

For constructability improvement in engineering and procurement phases of the project, seven concepts were examined and presented by (O'Connor, Rusch, and Schulz 1987) which addresses accessibility of workforce, resources, and equipment to facilitate building in severe weather and specification improvement. In addition to this, Construction-driven timelines, module/preassembly design and simple and standardized design elements which can facilitate manufacturing, shipping, and fitting are all supported by these concepts.

Implementing constructability can be done informally or formally. Based on this research, informal approach; formal project level; and comprehensive tracking are the following three techniques identified. Within this hierarchical structure of decision tiers, individual assessment of owner and project characteristics resulting in a single conclusion of a formal or informal approach; combining owner and project characteristics into a single conclusion of an informal or formal approach; and if a formal approach is determined, a decision must be made regarding formal project level tracking or comprehensive tracking, are the three stages. A framework of variables characterised by parameters has also been devised to evaluate project attributes and owner. (Gugel and Russell 1994)

According to the paper published by (Fischer and Tatum 1997) which states, to accomplish higher constructability, role of designers is important and this constructability should be priority objective included in all phases of the construction project. Lack of standard, precise constructability knowledge base that can be shared in form of database with parties involved links constructability issues to design decisions as claimed by the author is a reason for majority of projects not receiving constructability inputs despite the multiple benefits indicated by prior studies. This links constructability issues to design decisions.To help improve project constructability a thorough analysis on constructability uncovered some available tools.(Fisher, Anderson, and Rahman 2000).

Using CII Constructability Implementation Task Force's data and other current constructability-implementation efforts, a model was devised by (Radtke and Russell 1993) for application of constructability at the project level. The objective of this model was to serve as a guide for owners to gain maximum profits by using constructability improvement in their construction projects. Advance knowledge of costs and benefits connected with each approach, identifying the input needed from the owner are some methods described in detail in order to provide project managers with the information they need to make an informed decision about how constructability implementation programmes should be executed.(Russell, Gugel, and Radtke 1994).

To enhance constructability researchers, in their early studies sought ideas that could be applied across the project's stages along with an exhaustive investigation to examine how

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prefabrication, preassembling, and modularization might help construction and benefits that they may entail (Felix T. Uhlik and Georgina V. Lores 1998).

According to (Paulson 1976), while showing value of incorporating construction knowledge into design stated that a project's construction and cost can be significantly influenced by decisions taken early on. Furthermore, (Arditi, Elhassan, and Toklu 2002) discovered and ranked constructability benefits in design firms.

Numerous scholars and organisations analysed that there is constant use of constructability be it consciously or unconsciously. Constructability enhances a project's construction process by integrating knowledge and experience at all phases of the project to fulfil the project's ultimate objectives. A construction project lifecycle namely, scope definitions, activities, planning, design, execution, and operation can be briefed in pre-implementation and implementation stages. By detecting potential roadblocks, reduction and/or prevention of mistakes, time and cost overruns can be avoided by application of constructability pre-implementation stage (Jadidoleslami et al. 2018) and increases quality and safety (Russell and Gugel 1993).

(Russell and Gugel 1993), summarized advantage of constructability into qualitative and quantitative groups. The former consists of better problem avoidance, easier access to the site, fewer barriers, easier construction, lower maintenance costs, increased safety, fewer duplications, increased commitment of the project team, better communication and teamwork, better protection of equipment, less transportation, and enhanced productivity. The latter includes reduction of engineering expenses and the reduction of construction time and expenditures in terms of labours, materials, equipment.

3 DSM (DESIGN STRUCTURE MATRIX)

(Yassine 2004) describes DSM as a “compact, matrix representation of a project network. The matrix contains a list of all constituent activities and the corresponding information exchange patterns. That is, what information pieces (parameters) are required to start a certain activity and where does the information generated by that activity feed into (i.e., which other tasks within the matrix utilize the output information). The DSM provide insights about how to manage a complex project and highlights issues of information needs and requirements, task sequencing, and iterations”.

Also known as “Dependency Structure Matrix” (Danilovic and Browning 2007) few other names for DSM (Design Structure Matrix) are termed as Problem-Solving Matrix (PSM) and Design Precedence Matrix (Anon n.d.). DSM makes it easy to keep track of possible "process failure modes" and how they affect other tasks (Browning and Eppinger 2002).

A DSM can be created using two-step process i.e., Building/Creating the Design Structure Matrix which includes identification of list of activities, receiving feedback from experts, entering of matrix marks (x or •) and validation of prepared DSM. The second step, Project Redesign Partitioning, Tearing, Banding and Clustering of the activities (Yassine 2004).

(Fazio et al. 1988) mentions few popular schedule compression techniques which are still use today like phased construction, fast track, concurrent engineering (CE), and concurrent construction (CC) helps in reducing the project’s duration. Although substantial DSM research has been conducted in manufacturing and other fields, construction has received relatively little attention. Case studies carried out by construction researchers at VTT (Technical Research

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Centre of Finland) and Loughborough University showcased the use of DSM for developing more effective sequences in the design process (HUOVILA et al. 2010) and devised ADePT (Analytical Design Planning Technique), DSM-based methodology with its usability evaluated in construction projects (Austin et al. 2000).

4 METHODOLOGY

A hypothetical case of a residential building was formed which will be used in planning, design and construction phases. The interrelationships between typical construction activities and constructability activities were explored using a Dependency Structure Matrix developed with DSM Matrix software. These results were compared to a sample project with similar time dimensions, and final results were produced. (Fig.1, Fig. 2)

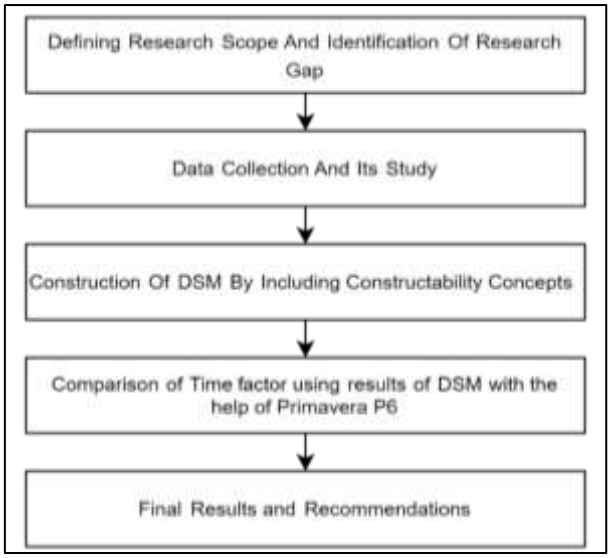

Fig. 1 *Overall Methodology Process*

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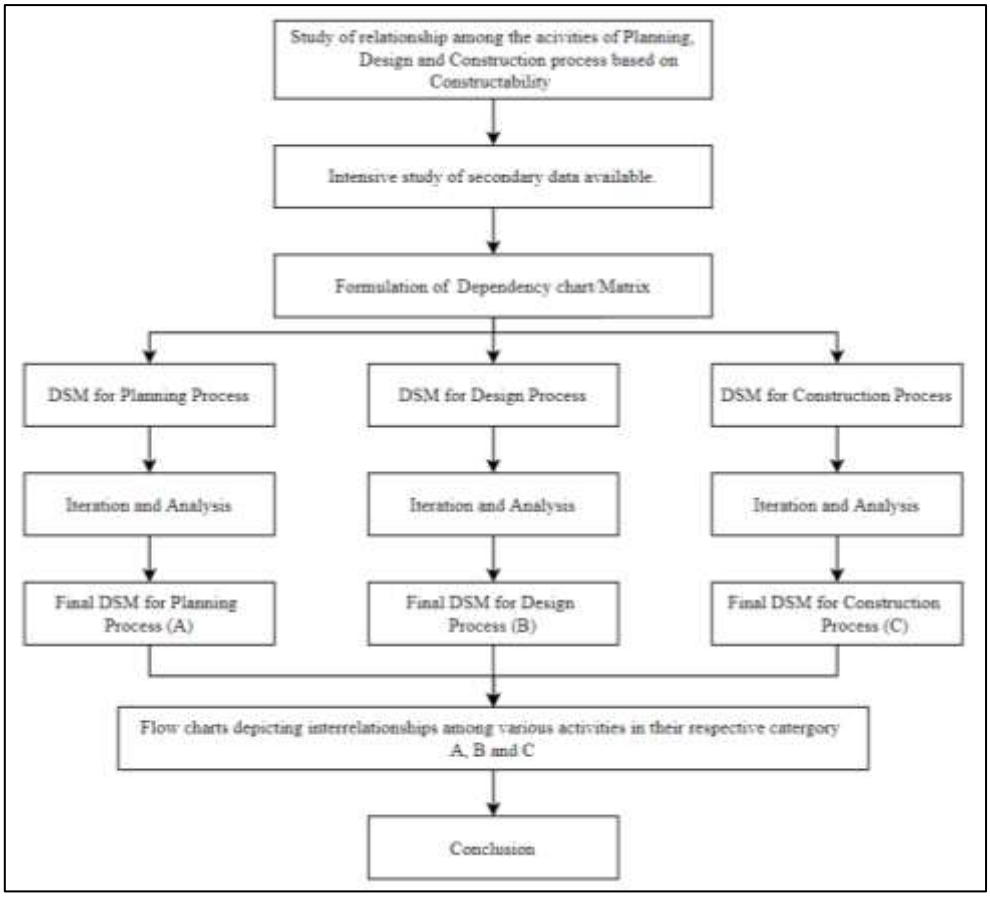

Fig. 2 *Methodology for Planning, Design and Construction Phase using DSM*

5 MATERIALS AND METHOD

A hypothetical case of a residential building was formed. Consider one residential building project being constructed in Pune city. The project details are as follows:

Tab. 1 *Details of planning phase for residential building project*

S.No.	Item	Description
1	**Name of the project**	SAJKA Township
2	**Project Type**	Residential
3	**Total Plot area**	6475.2 sqm
4	**Built up Area**	7757.6 sqm
5	**Location**	Pune, Maharashtra
6	**Baseline Start Date (Planning Phase)**	1-Jan-21
7	**Baseline End Date**	3-Sep-21
8	**Baseline start Date (Design Phase)**	6-Sep-21
9	**Baseline End Date**	9-Feb-22
10	**Baseline start Date (Construction Phase)**	1-Feb-22
11	**Baseline End Date**	22-May-24
12	**Total project duration**	1082 days ~ 3 years

Activities were considered for the planning, design and construction phases are as follows:

Planning phase:

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- Site Info (site particulars, access roads, nearby buildings, Photographs)
- Selection of Architect
- Bylaws Applicable (setbacks, building Heights, FSI etc.)
- Target Saleable Area & area calculations.
- Product mix
- Room Sizing, preliminary typical floor plans
- Site Survey, Tree Survey & Plot working
- Comparison of surveying plans
- Detailed rendering of the project
- Appointment of All consultants.
- Shortlisting of Contractors
- Comparison of alternatives for core construction
- Working out Construction Schedule
- Laying out site efficiently
- Simplification of technical specifications
- Review and implementation of past lessons learned

Design Phase:

- Municipal Norms
- Design and Specifications Standards
- Site Plan zoning
- Drawing for municipal Approval
- Drawing for Fire Engine Approval
- Design Drawings set
- GFC Drawings set
- Proposed material specifications if any
- Preliminary 3D Elevations
- Landscape Concept Design
- Structural Drawings
- MEP Drawings

Construction phase:

- Tower Construction
- UGWT
- Drainage Works
- STP Works
- LT with Transformer Work External electrical work
- Road Work
- Compound wall
- Landscape Works
- Handover of Project

6 CONSTRUCTABILITY IN PLANNING PHASE

Considering a situation where the client (builder) started the project by arranging the necessary funds, resources etc. according to the anticipated cost and time. Currently the project is in planning stage. After certain point of time, the client approached the construction manager and discussed about his project. He is worried that his project might not go with anticipated time and cost and he may land in loss. After listening to him, the construction manager being a specialist in constructability suggested him appropriate solution, so that he might come out with minimal or no loss or with profit from that project.

The planning phase has a set of 16 activities interlinked using the constructability knowledge. (Tab. 2)

Tab. 2 *Planning Phase activities with their interdependencies*

S.No.	Activity	Dependency
1	Site Info (site particulars, access roads, nearby buildings, Photographs)	Independent
2	Selection of Architect	Independent

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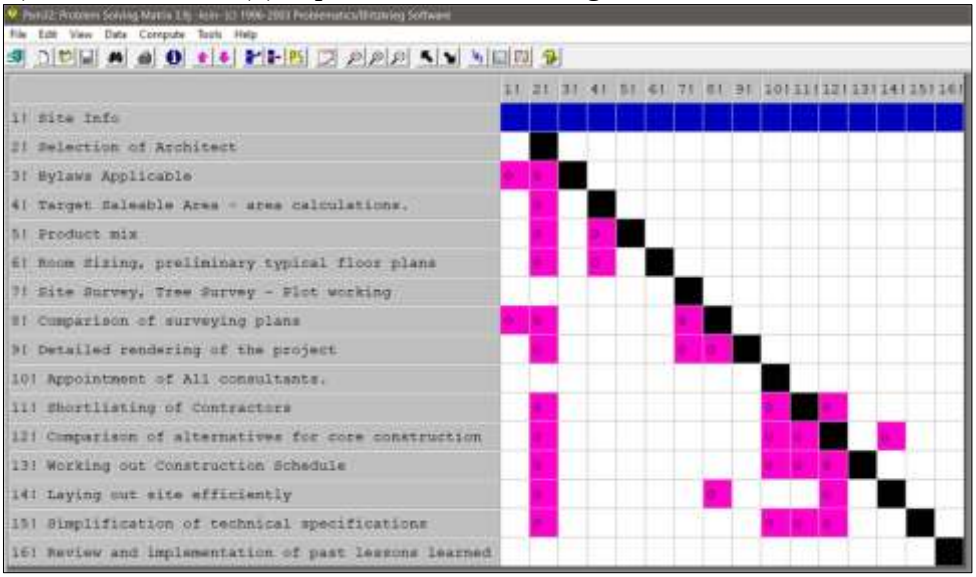
3	Bylaws Applicable (setbacks, building Heights, FSI etc.)	1,2
4	Target Saleable Area & area calculations.	2
5	Product mix	2,4
6	Room Sizing, preliminary typical floor plans	2,4
7	Site Survey, Tree Survey & Plot working	Independent
8	Comparison of surveying plans	1,2,7
9	Detailed rendering of the project	2,7,8
10	Appointment of All consultants.	Independent
11	Shortlisting of Contractors	2,10,12
12	Comparison of alternatives for core construction	2,10,11,14
13	Working out Construction Schedule	2,10,11,12
14	Laying out site efficiently	2,8,12
15	Simplification of technical specifications	2,10,11,12
16	Review and implementation of past lessons learned	Independent

6.1 Creation of DSM

All activities are then represented in DSM. The black cells represent the diagonal. Firstly, partitioning of activities is done which rearranges the DSM into block of activities. The marks (0) in the block above the diagonal are considered as assumptions and if assumptions are valid, gives a Critical Path network below diagonal.

The principal circuit represented by yellow boxes helps is deciding the activities which needs to be teared to break the looping and thus a final matrix is formed after rearranging the activities (green box) where no mark (0) is present above the diagonal.



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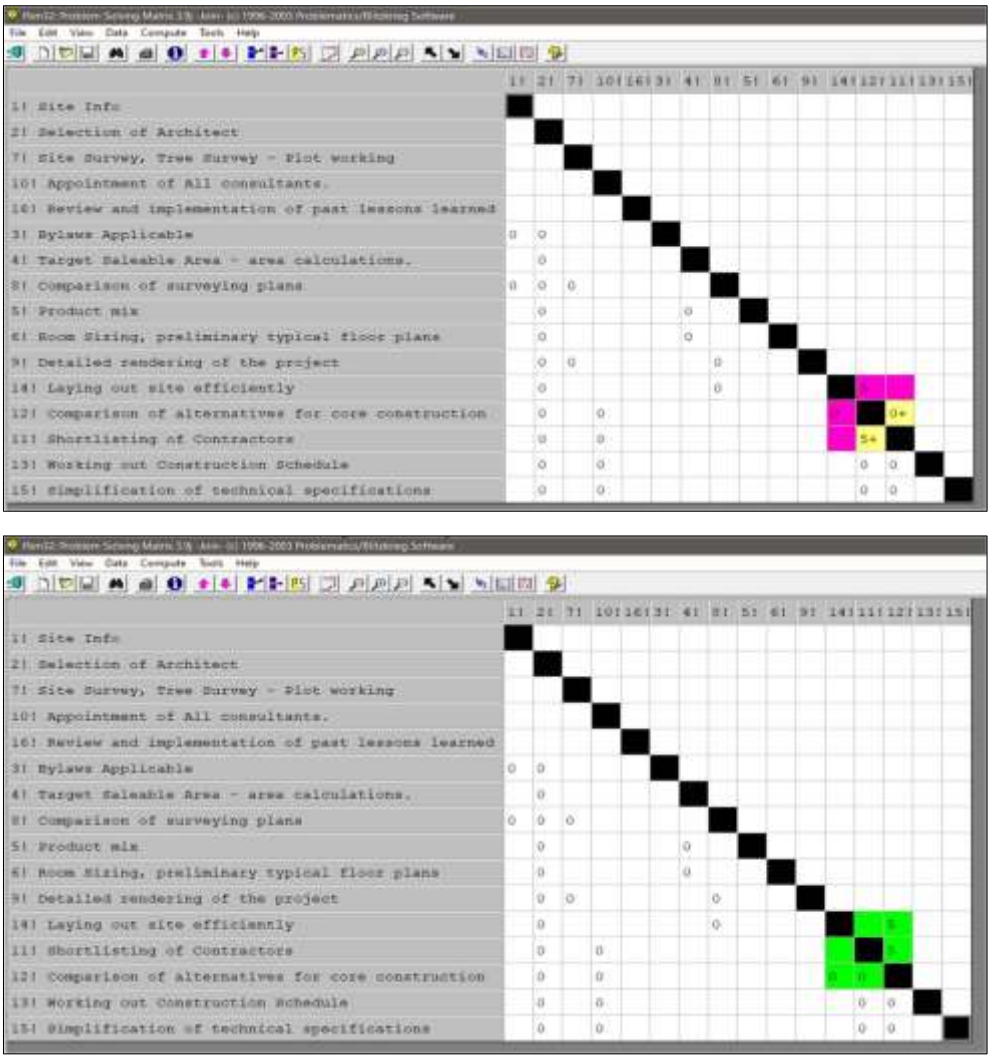

Fig. 3 *Stepwise formation and obtaining final DSM after partitioning and tearing (Planning Phase)*

From the final DSM we can deduce the following interpretations:

- Activities 1,2,7,10 can be started simultaneously.
- Activity 3 is dependent on activity 1 and 2.
- Product mix (activity 5) can be started after activities 2 and 4 are completed.
- For shortlisting the contractors (activity 11), activity 2 and 7 needs to be completed.
- Activities 13,15 can be worked out simultaneously i.e., parallel activities and are successors to activities 11 and 12.
- Since, activity 16 is independent it can used throughout the planning process.

After obtaining the final DSM, the activities are scheduled in Primavera to calculate final completion duration and total cost of project. These results are then compared with sample project taken of same dimensions and the results were obtained.

6.2 Scheduling and Gantt Chart

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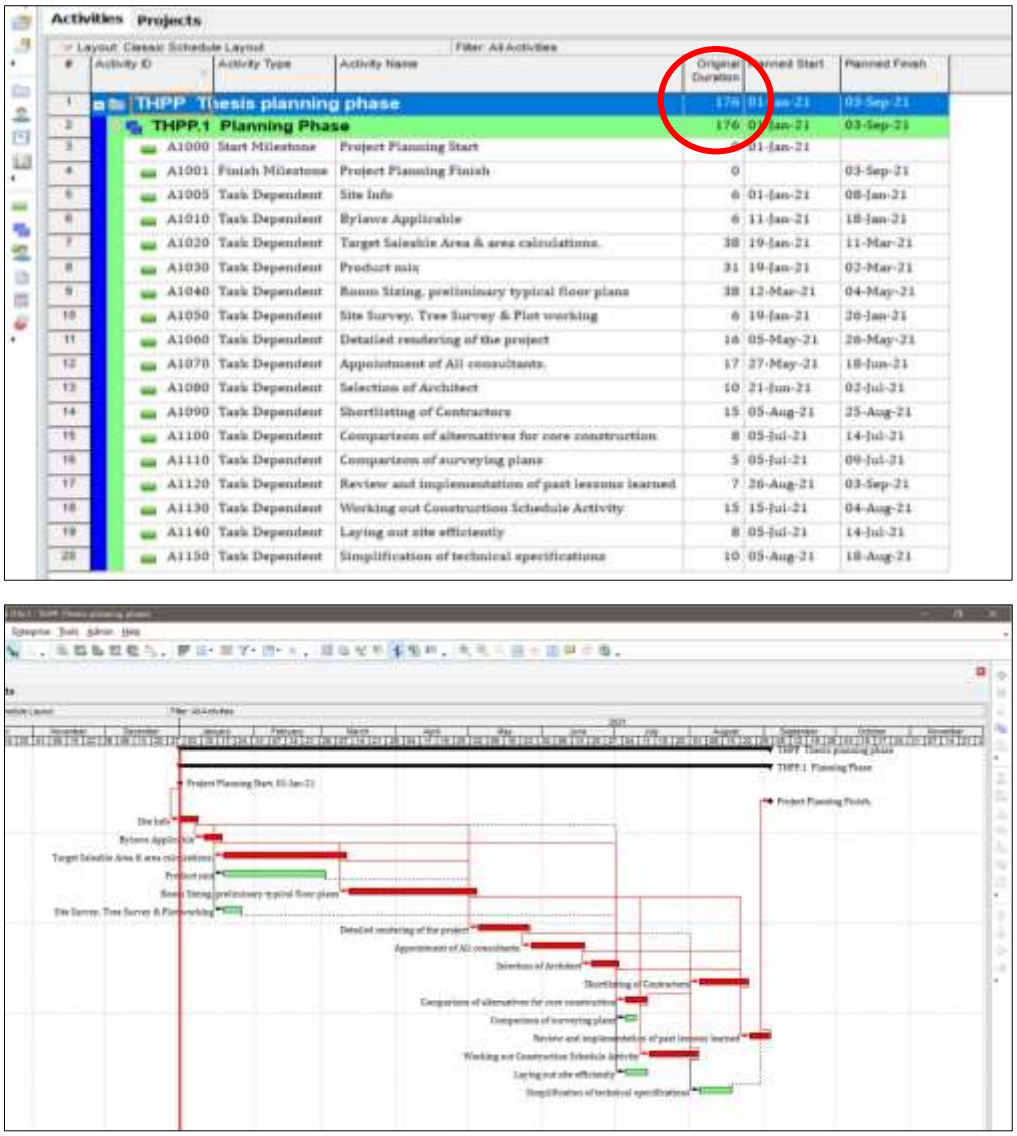

#	Activity ID	Activity Type	Activity Name	Original Duration	Planned Start	Planned Finish
1	THPP	Thesis planning phase		176	01-Jan-21	03-Sep-21
2	THPP.1	Planning Phase		176	01-Jan-21	03-Sep-21
3	A1000	Start Milestone	Project Planning Start	0	01-Jan-21	
4	A1001	Finish Milestone	Project Planning Finish	0		03-Sep-21
5	A1005	Task Dependent	Site Info	6	01-Jan-21	08-Jan-21
6	A1010	Task Dependent	Bylaws Applicable	6	11-Jan-21	18-Jan-21
7	A1020	Task Dependent	Target Saleable Area & area calculations.	38	19-Jan-21	11-Mar-21
8	A1030	Task Dependent	Product mix	31	19-Jan-21	02-Mar-21
9	A1040	Task Dependent	Rooms Sizing, preliminary typical floor plans	38	12-Mar-21	04-May-21
10	A1050	Task Dependent	Site Survey, Tree Survey & Plot working	6	19-Jan-21	26-Jan-21
11	A1060	Task Dependent	Detailed rendering of the project	16	05-May-21	26-May-21
12	A1070	Task Dependent	Appointment of All consultants.	17	27-May-21	18-Jun-21
13	A1080	Task Dependent	Selection of Architect	10	21-Jun-21	02-Jul-21
14	A1090	Task Dependent	Shortlisting of Contractors	15	05-Aug-21	25-Aug-21
15	A1100	Task Dependent	Comparison of alternatives for core construction	8	05-Jul-21	14-Jul-21
16	A1110	Task Dependent	Comparison of surveying plans	5	05-Jul-21	09-Jul-21
17	A1120	Task Dependent	Review and implementation of past lessons learned	7	26-Aug-21	03-Sep-21
18	A1130	Task Dependent	Working out Construction Schedule Activity	15	15-Jul-21	04-Aug-21
19	A1140	Task Dependent	Laying out site efficiently	8	05-Jul-21	14-Jul-21
20	A1150	Task Dependent	Simplification of technical specifications	10	05-Aug-21	18-Aug-21

Fig. 4 *Original schedule and Gantt chart view of scheduled activities as prepared by the client (Planning Phase)*

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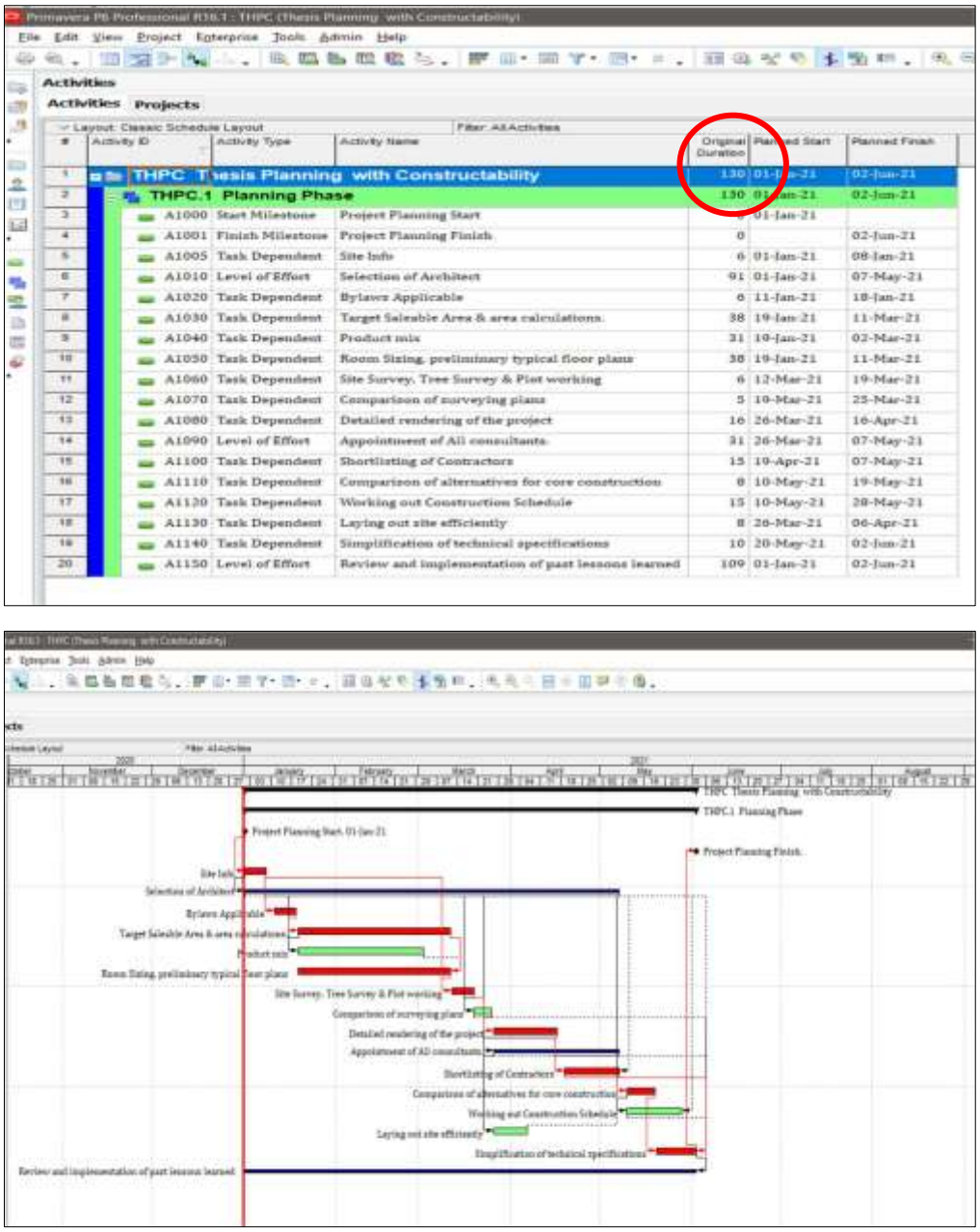

Fig. 5 *New planning schedule and Gantt chart view from the DSM obtained*

We can see the original planned duration for the project is 176 days. From the Gantt chart (Fig. 4) we can see the interdependencies among the activities. As there is no mention of clear roles and the activities have been connected to each other in improper sequence of their execution. There are high chances that problems will arise as the project will move forward. To solve this issue planning activities can be scheduled in more specific way with the use of proper constructability knowledge. Thus, there will be no time overrun situation from that project which can further help in designing and construction phase for their smooth functioning.

7 CONSTRUCTABILITY IN DESIGN PHASE

Now, considering the client approached the construction manager after planning stage (without concept of constructability) and at the design stage he wants to introduce constructability. The design phase has a set of 12 activities interlinked using the constructability knowledge (Tab. 3).

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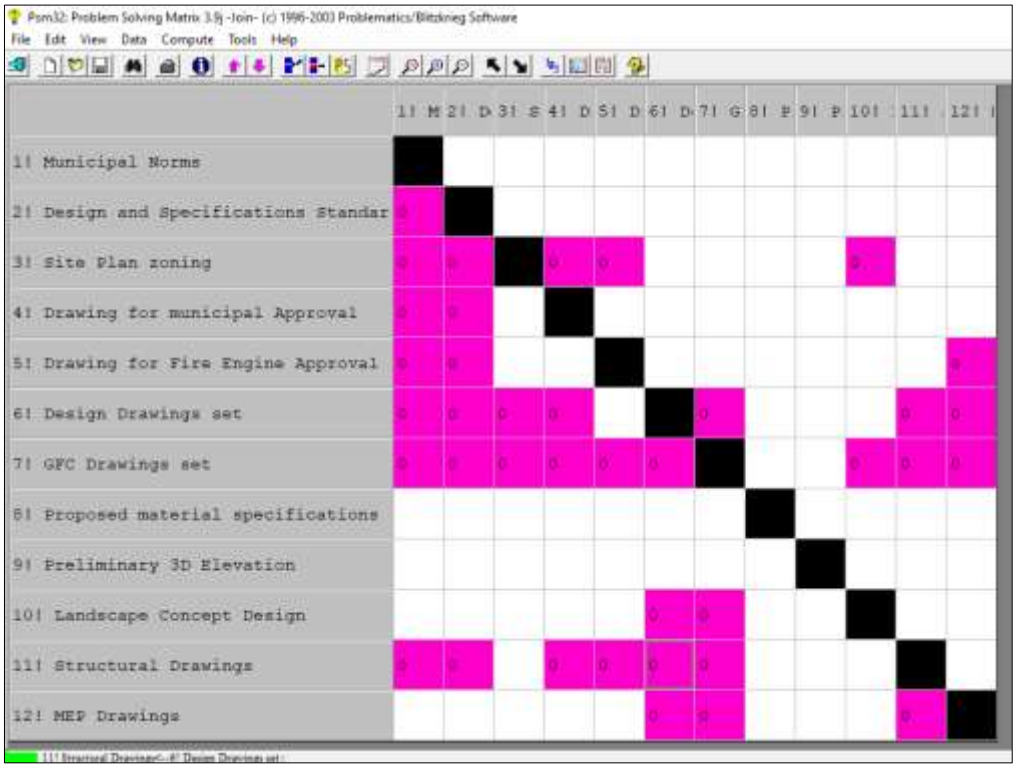
Tab. 3 *List of activities in Design phase and their relationship with other activities*

S.No.	Activity	Dependency
1	Municipal Norms	Independent
2	Design and Specifications Standards	1
3	Site Plan zoning	1,2,4,5,10
4	Drawing for municipal Approval	1,2
5	Drawing for Fire Engine Approval	1,2,12
6	Design Drawings set	1,2,3,4,7,11,12
7	GFC Drawings set	1,2,3,4,5,6,10,11,12
8	Proposed material specifications if any	Independent
9	Preliminary 3D Elevations	Independent
10	Landscape Concept Design	6,7
11	Structural Drawings	1,2,4,5,6,7
12	MEP Drawings	6,7,11

7.1 Creation of DSM



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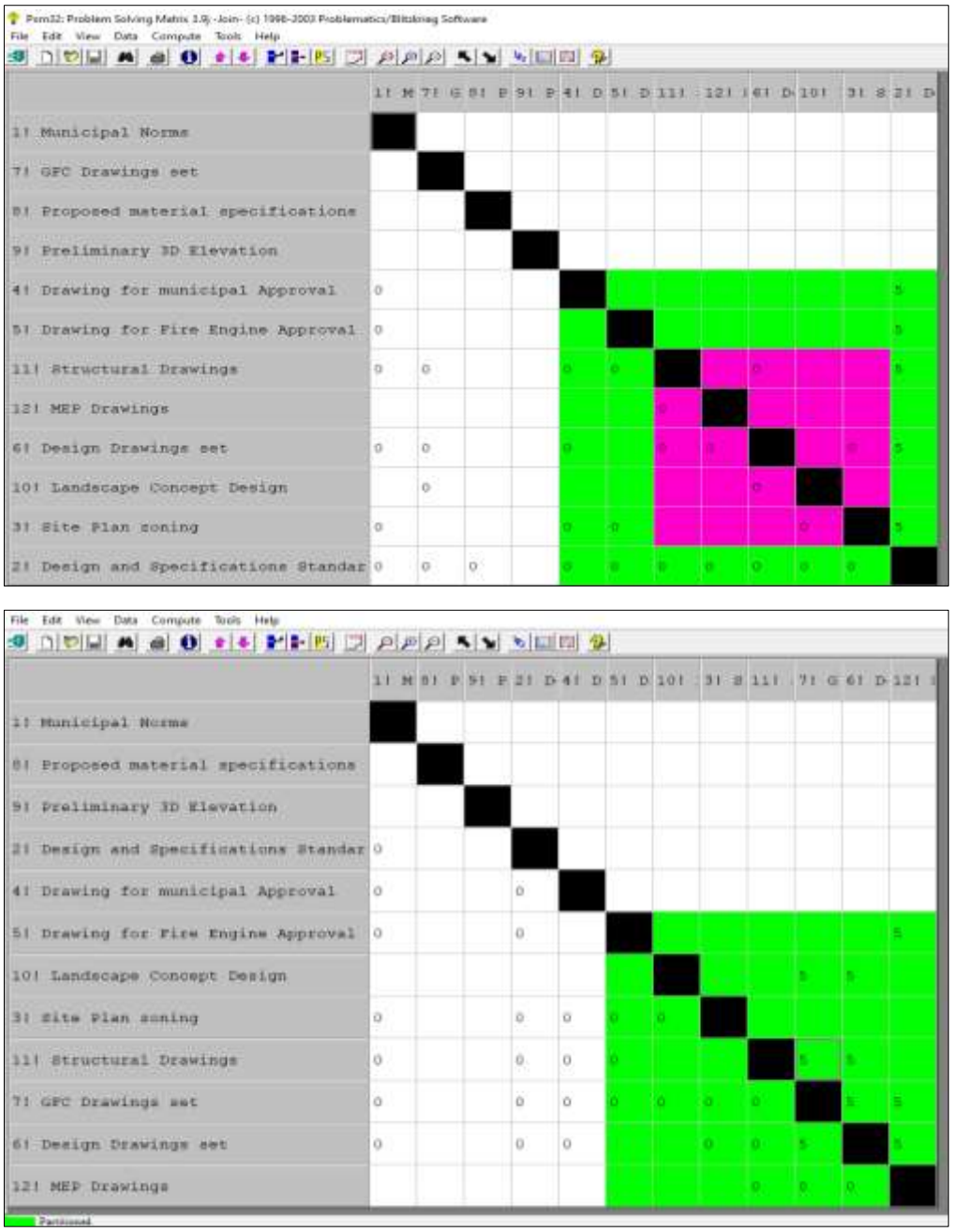

Fig. 6 *Stepwise formation and obtaining final DSM after partitioning and tearing (Design Phase)*

- Municipal norms have an impact on Drawing for municipal Approval, drawing for Fire Engine Approval, Structural Drawings, Design Drawings set, Site Plan zoning, GFC drawing and Design and Specifications Standards.
- Design and Specifications Standards have an impact on Drawing for Municipal Approval, drawing for Fire Engine Approval, Site Plan Zoning, Structural Drawings, GFC drawing and Design Drawings set.
- Drawing for Municipal Approval has an impact on Structural Drawings, Design Drawings set, Site Plan zoning and Design and GFC drawing.
- Drawing for Fire Engine Approval has an impact on Structural Drawings, Site Plan zoning, Design Drawings set and Design and GFC drawing.
- Landscape Concept Design has an impact on Site Plan zoning and GFC drawing.

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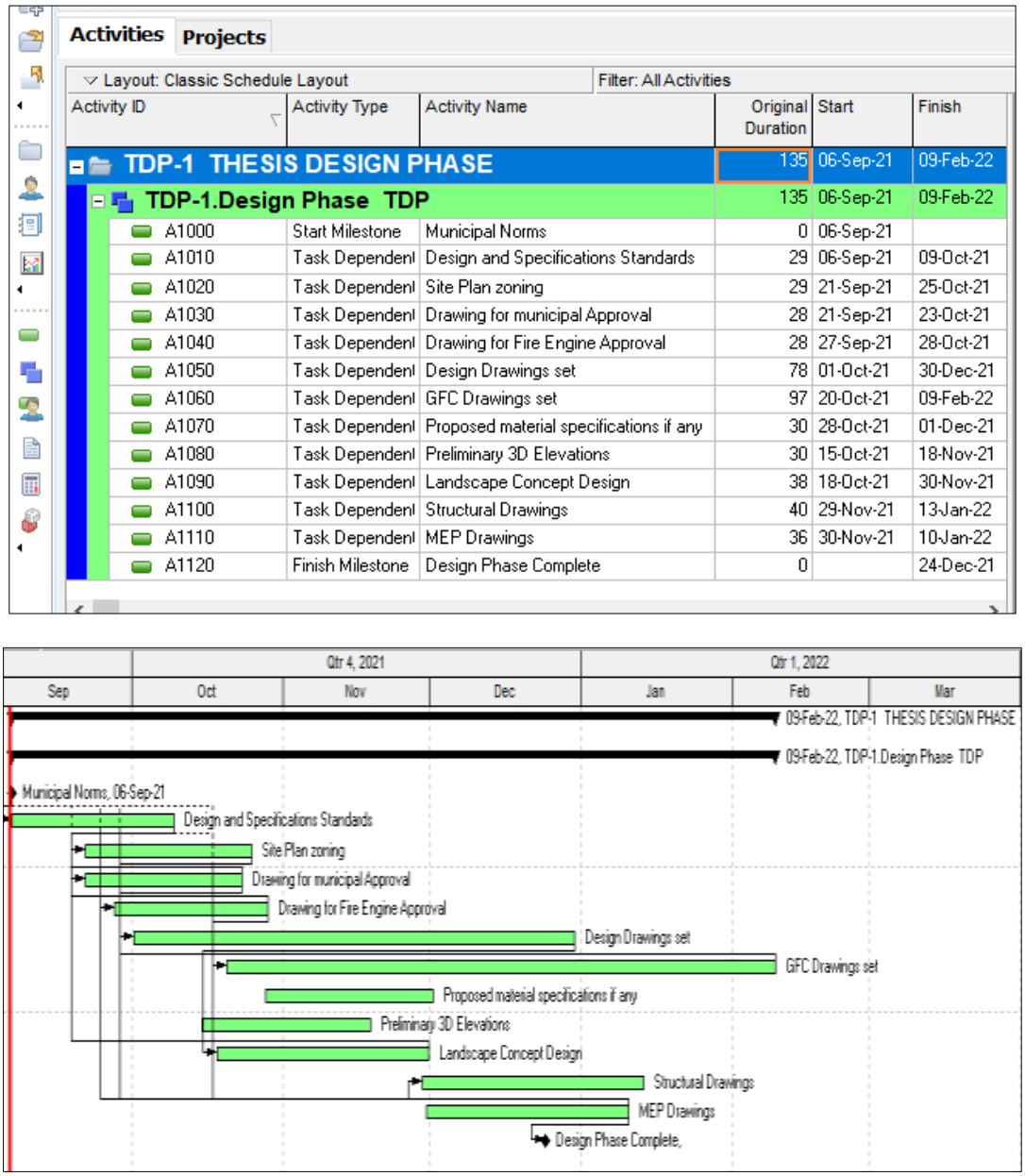
- Site Plan zoning has an impact on, Design Drawings set and Design and GFC drawing.
- Structural Drawings has an impact on GFC drawing, MEP Drawings and Design Drawings set.
- GFC drawing set has an impact on MEP Drawings.

7.2 Scheduling and Gantt Chart

Here we can see the original planned duration for the project is 135 days. From the Gantt chart we can see the interdependencies among the activities. As there is no mention of clear roles and the activities have been connected to each other in improper sequence of their execution. There are high chances that problems will arise as the project will move forward. To solve this issue design activity can be scheduled in more specific way with the use of proper constructability knowledge.



Activities | Projects

Layout: Classic Schedule Layout | Filter: All Activities

Activity ID	Activity Type	Activity Name	Original Duration	Start	Finish
TDP-1 THESIS DESIGN PHASE			135	06-Sep-21	09-Feb-22
TDP-1.Design Phase TDP			135	06-Sep-21	09-Feb-22
A1000	Start Milestone	Municipal Norms	0	06-Sep-21	
A1010	Task Dependent	Design and Specifications Standards	29	06-Sep-21	09-Oct-21
A1020	Task Dependent	Site Plan zoning	29	21-Sep-21	25-Oct-21
A1030	Task Dependent	Drawing for municipal Approval	28	21-Sep-21	23-Oct-21
A1040	Task Dependent	Drawing for Fire Engine Approval	28	27-Sep-21	28-Oct-21
A1050	Task Dependent	Design Drawings set	78	01-Oct-21	30-Dec-21
A1060	Task Dependent	GFC Drawings set	97	20-Oct-21	09-Feb-22
A1070	Task Dependent	Proposed material specifications if any	30	28-Oct-21	01-Dec-21
A1080	Task Dependent	Preliminary 3D Elevations	30	15-Oct-21	18-Nov-21
A1090	Task Dependent	Landscape Concept Design	38	18-Oct-21	30-Nov-21
A1100	Task Dependent	Structural Drawings	40	29-Nov-21	13-Jan-22
A1110	Task Dependent	MEP Drawings	36	30-Nov-21	10-Jan-22
A1120	Finish Milestone	Design Phase Complete	0		24-Dec-21

Fig. 7 *Original schedule and Gantt chart view of scheduled activities as prepared by the client (Design Phase)*

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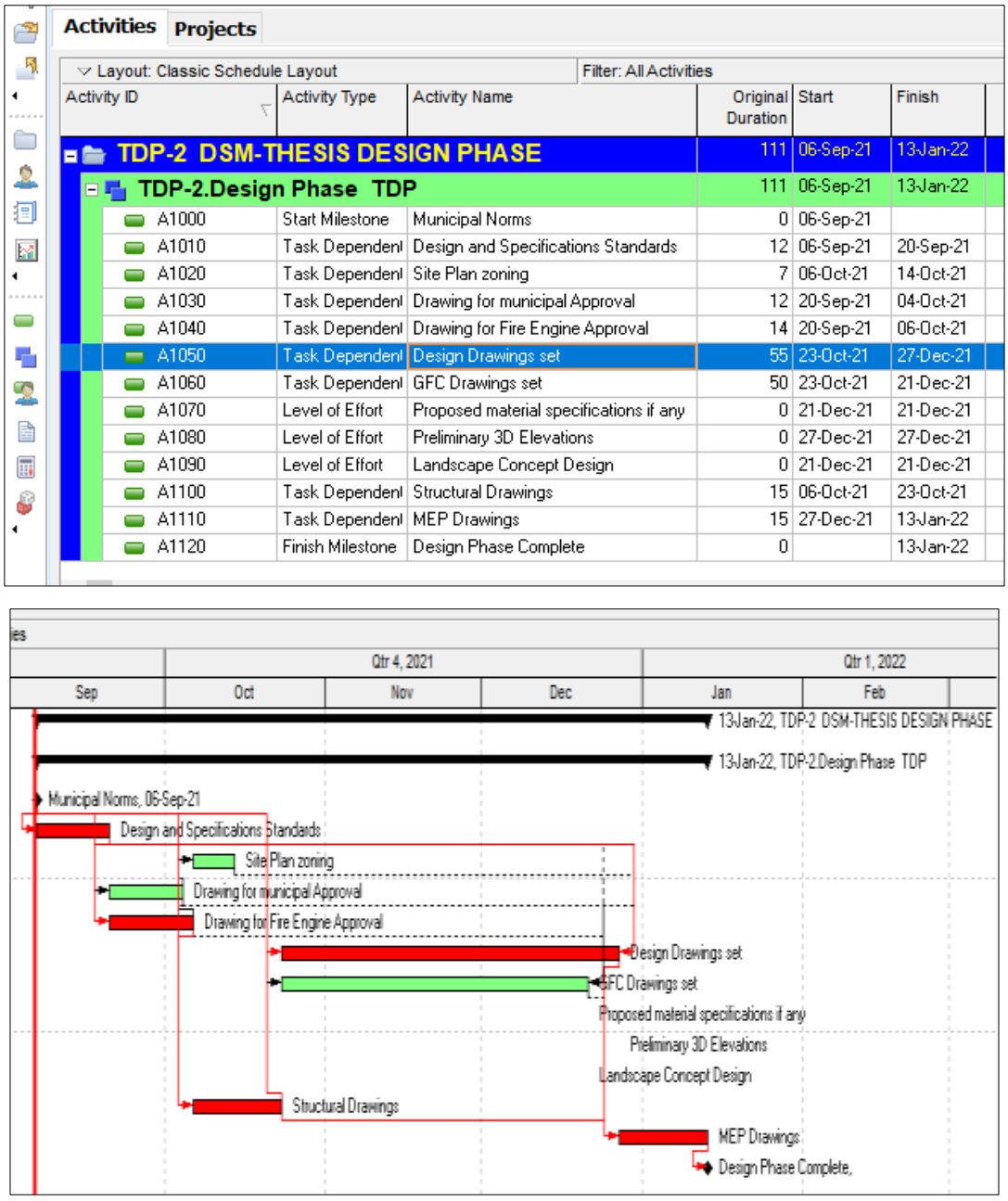

Fig. 8 *New design schedule and Gantt chart view from the DSM obtained*

After rescheduling the design stage activities using the constructability knowledge by assigning the activities as per their specific role, they will perform during the whole design phase we can see the reduction in duration from 135 days to 111 days. Thus, there will be no time overrun situation from that project which can further help in construction phase for their smooth functioning.

8 CONSTRUCTABILITY IN CONSTRUCTION PHASE

Consider client approached the construction manager after design stage (without concept of constructability either at planning or design phase), but he wants to implement at construction

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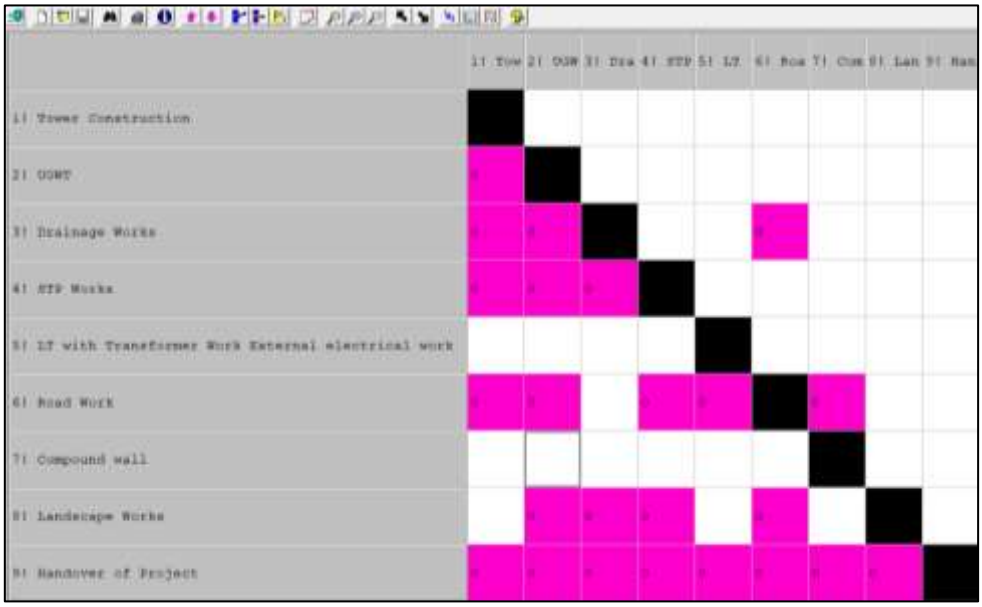
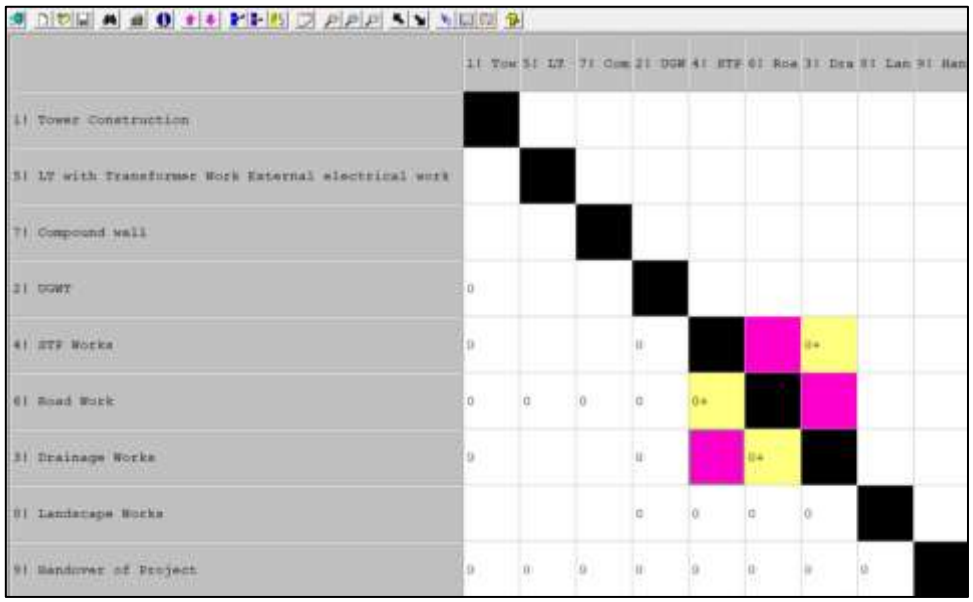
phase. The construction phase has a set of 9 major activities interlinked using the constructability knowledge (Tab. 4).

Tab. 4 *List of activities in Construction Phase and their relationship with other activities*

S.NO.	Activity	Dependency
1	Tower Construction	Independent
2	UGWT	1
3	Drainage Works	1,2,6
4	STP Works	1,2,3
5	LT with Transformer Work External electrical work	Independent
6	Road Work	1,2,4,5,7
7	Compound wall	Independent
8	Landscape Works	2,3,4,6
9	Handover of Project	1,2,3,4,5,6,7,8

8.1 Creation of DSM





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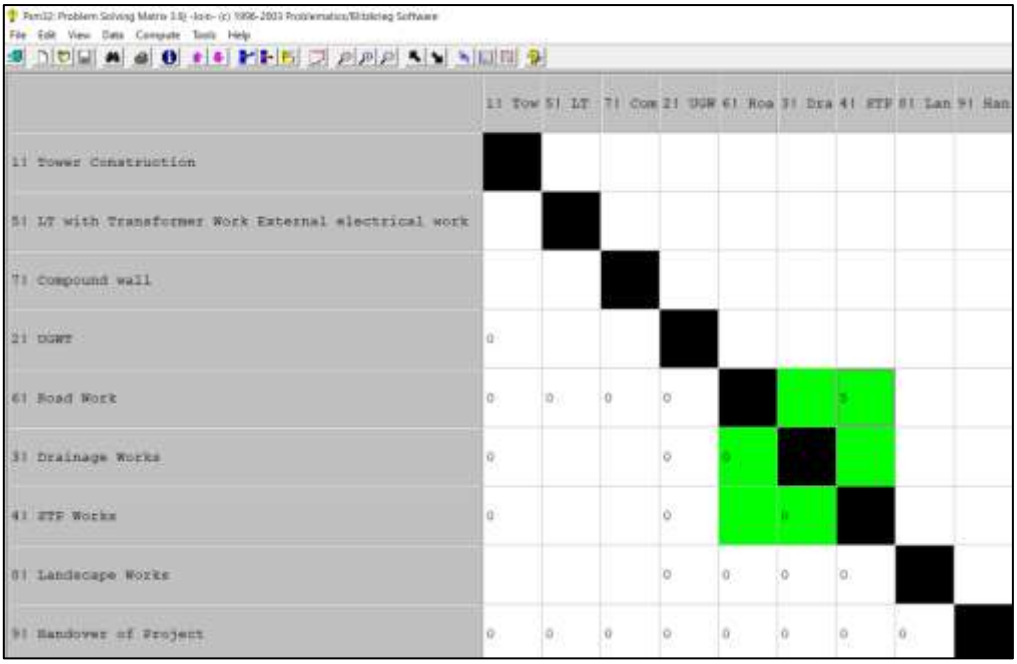
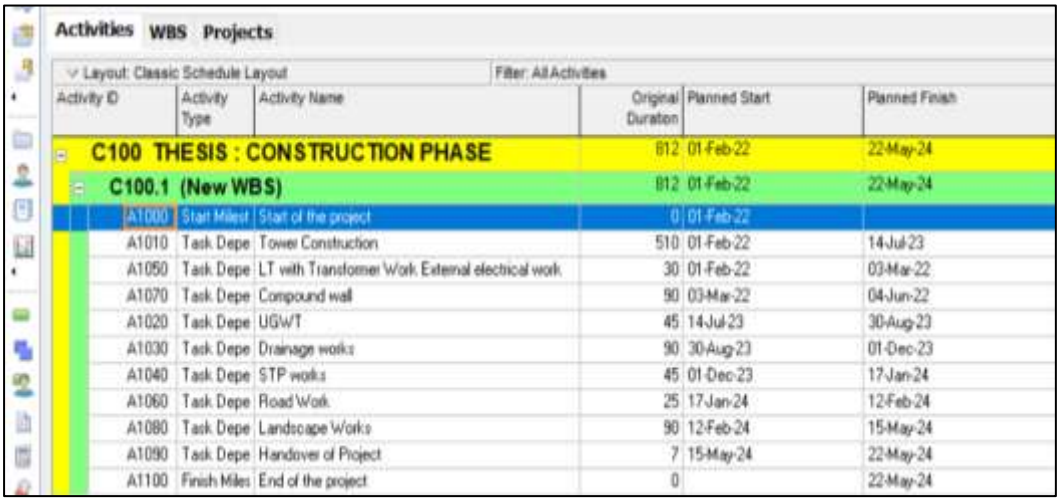


Fig. 9 *Stepwise formation and obtaining final DSM after partitioning and tearing (Construction Phase)*

- Tower construction has an impact on UGWT, Road works, Drainage works, STP works and handover of the project.
- LT with Transformer Work External electrical work has an impact on Road works and handover of the project.
- Compound wall has an impact on Road works and handover of the project.
- UGWT activity has an impact on Road works, Drainage works, STP works, Landscape works and handover of the project.
- Road works activity has an impact on Drainage works, Landscape works and handover of the project.
- Drainage works activity has an impact on STP works, Landscape works and handover of the project.
- STP works activity has an impact on Landscape works and handover of the project.
- Landscape works activity has an impact on handover of the project.

8.2 Scheduling and Gantt Chart



Activities | WBS | Projects

Layout: Classic Schedule Layout | Filter: All Activities

Activity ID	Activity Type	Activity Name	Original Duration	Planned Start	Planned Finish
C100		THESIS : CONSTRUCTION PHASE	812	01-Feb-22	22-May-24
C100.1		(New WBS)	812	01-Feb-22	22-May-24
A1000	Start Milest	Start of the project	0	01-Feb-22	
A1010	Task Depe	Tower Construction	510	01-Feb-22	14-Jul-23
A1050	Task Depe	LT with Transformer Work External electrical work	30	01-Feb-22	03-Mar-22
A1070	Task Depe	Compound wall	90	03-Mar-22	04-Jun-22
A1020	Task Depe	UGWT	45	14-Jul-23	30-Aug-23
A1030	Task Depe	Drainage works	90	30-Aug-23	01-Dec-23
A1040	Task Depe	STP works	45	01-Dec-23	17-Jan-24
A1060	Task Depe	Road Work	25	17-Jan-24	12-Feb-24
A1080	Task Depe	Landscape Works	90	12-Feb-24	15-May-24
A1090	Task Depe	Handover of Project	7	15-May-24	22-May-24
A1100	Finish Miles	End of the project	0		22-May-24

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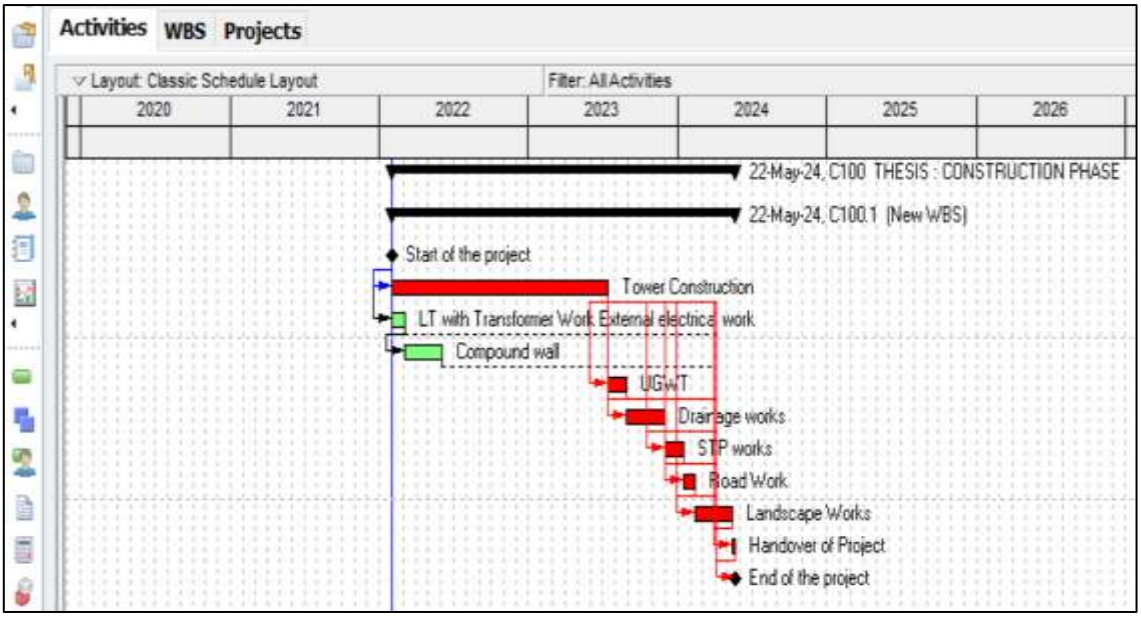
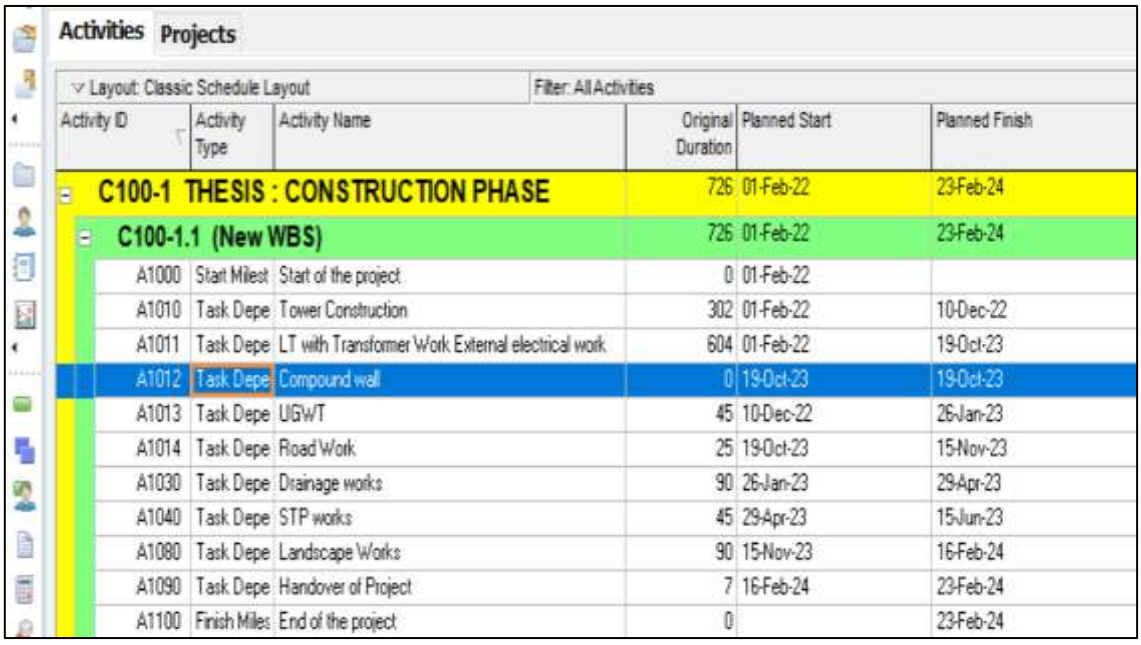


Fig. 10 *Original schedule and Gantt chart view of scheduled activities as prepared by the client (Construction Phase)*

As per the planning and scheduling, the total duration of the project is 812 days (1st Feb. 2022 to 22nd May 2024). So, to implement constructability, the above-mentioned activities were framed and then stated whether each of the activities mentioned was dependent or independent. After rescheduling the construction stage activities using the constructability knowledge by assigning the activities as per their specific roles, they will perform during the whole constructability phase we can see the reduction in duration from 812 days to 726 days.



Activity ID	Activity Type	Activity Name	Original Duration	Planned Start	Planned Finish
C100-1	THESIS : CONSTRUCTION PHASE		726	01-Feb-22	23-Feb-24
C100-1.1	(New WBS)		726	01-Feb-22	23-Feb-24
A1000	Start Milest	Start of the project	0	01-Feb-22	
A1010	Task Depe	Tower Construction	302	01-Feb-22	10-Dec-22
A1011	Task Depe	LT with Transformer Work External electrical work	604	01-Feb-22	19-Oct-23
A1012	Task Depe	Compound wall	0	19-Oct-23	19-Oct-23
A1013	Task Depe	UGWT	45	10-Dec-22	26-Jan-23
A1014	Task Depe	Road Work	25	19-Oct-23	15-Nov-23
A1030	Task Depe	Drainage works	90	26-Jan-23	29-Apr-23
A1040	Task Depe	STP works	45	29-Apr-23	15-Jun-23
A1080	Task Depe	Landscape Works	90	15-Nov-23	16-Feb-24
A1090	Task Depe	Handover of Project	7	16-Feb-24	23-Feb-24
A1100	Finish Miles	End of the project	0		23-Feb-24

Research paper UGC CARE Listed (Group -I) Journal Volume 11, Iss 12, 2022

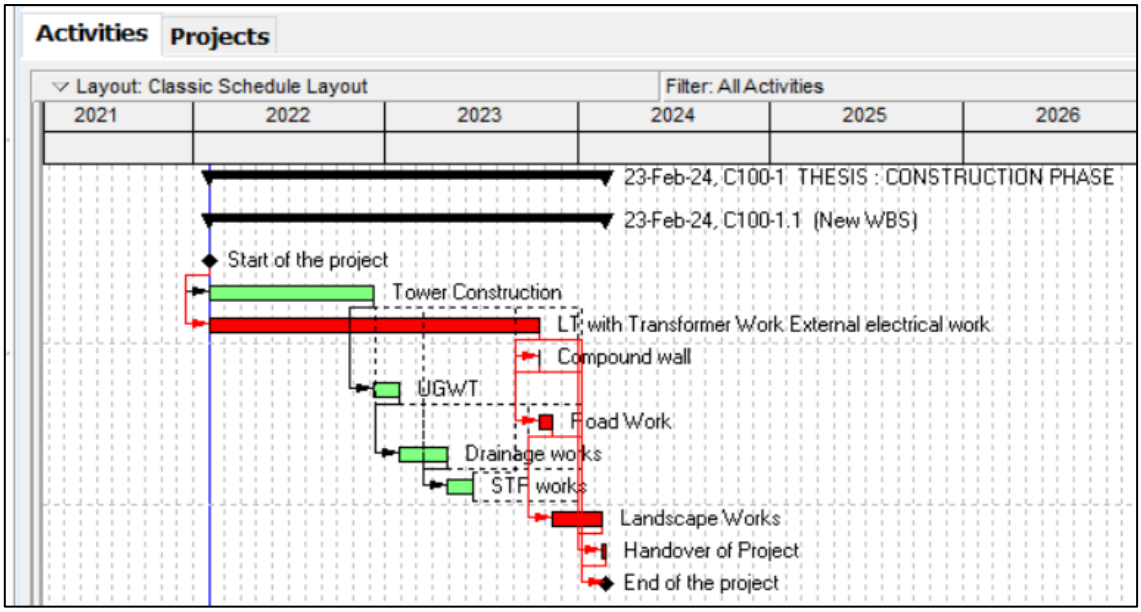


Fig. 11 *New construction schedule and Gantt chart view from the DSM obtained*

From the analysis it has been found that there is a total reduction of 86 days in overall duration of the construction phase as compared to initial schedule. Thus, there will be no time overrun situation from that project which can further help in handover of the project and operation phase for their smooth functioning.

9 Results Summary

The summarized view quantitative results are shown in Table 5 below. It is clearly deducted that total construction of residential apartment is assumed to be completed 115 days i.e., approximately 4 months prior to the estimated total duration (1082 days).

Tab. 5 *Comparison of results before and after implementing constructability*

S.No.	Description	Outcome
Planning Phase		
1.	**Original finish date**	3 Sept,2021
2.	Days for completion	176 days
3.	**New finish date**	2 June, 2021
4.	Days for completion	130 days
	Planning phase now will finish **46 days** earlier than estimated time	
Design Phase		
1.	**Original finish date**	9 Feb,2022
2.	Days for completion	135 days
3.	**New finish date**	13 Jan, 2022
4.	Days for completion	111 days
	Design phase will now finish **24 days** earlier than estimated time	
Construction Phase		
1.	**Original finish date**	22nd May 2024
2.	Days for completion	812 days
3.	**New finish date**	23rd Feb. 2024
4.	Days for completion	726 days

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	Construction phase now will finish **86 days** earlier than estimated time.
Remark: Total construction of residential apartment is assumed to be completed 115 days i.e., approximately 4 months prior to the estimated total duration.	

10 Conclusions

With increasing construction projects, implementation of constructability has become an imperial part in all the phases of construction (plan, design, construction and maintenance). Constructability is a notion that aims to eliminate the challenges that come with separating and demarcating contracting parties and procedures. Constructability must also take into account the myriad performance, technological, and organisational concerns that arise throughout the actual construction process.

This work has been carried out to determine effect of constructability knowledge on completion duration of residential building construction compared to an initially schedule. A system for incorporating constructability activities into the different phases of residential construction was developed. The proposed framework grouped constructability activities based on proper scheduling and taking into account the existing design activities' information flows. The results of this study will contribute to the improving efficiency in the customer satisfaction, deliver a high-quality service, and provide good value for money.

Effective constructability can only be achieved by collaboration among contractual parties and a focused effort in project cooperation, as is self-evident. Effective project connectedness will immediately result in improved buildability of the design philosophy, construction methodologies, and administrative procedures, but such benefits will also accrue as a result of the individuals' commitment and innovation. Constructability must be pushed in order to maximise attainable advantages without detracting from the end product's value, as these parameters are manipulated in conjunction with criteria for speed of construction and adherence to predicted budget.

11 Limitations and Future Scope

Although it is beneficial to identify the decision-making stages, a simple introduction at each decision-making point is insufficient to effectively utilise the proposed method. Some of the new areas where more effort is needed are as follows:

- This study’s main focus has been on time management. Cost and resource management can be considered as an extension of this research work.
- There could be several data transmissions across activities, and splitting the core activity into multiple sub-activities could result in larger, more sophisticated matrices, making control more difficult.
- The rework time is not taken into account when determining the size of the paper. In addition to the typical overlap, extra effort in calculating rework time can result in significant gains.
- Since this paper focused on residential project, further can be expanded to industrial and commercial projects.

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References

Anon. n.d. *The Design Structure Matrix (DSM).* Retrieved May 16, 2022 (https://dsmweb.org/).

Arditi, David, Ahmed Elhassan, and Y. Cengiz Toklu (2002) *Constructability Analysis in the Design Firm.* Journal of Construction Engineering and Management 128(2). DOI: 10.1061/(asce)0733-9364(2002)128:2(117).

Austin, S., A. Baldwin, B. Li, and P. Waskett (2000) *Integrating Design in the Project Process.* Proceedings of the Institution of Civil Engineers: Civil Engineering 138(4). DOI: 10.1680/cien.2000.138.4.177.

Browning, Tyson R., and Steven D. Eppinger (2002) *Modeling Impacts of Process Architecture on Cost and Schedule Risk in Product Development.* IEEE Transactions on Engineering Management 49(4). DOI: 10.1109/TEM.2002.806709.

Danilovic, Mike, and Tyson R. Browning (2007) *Managing Complex Product Development Projects with Design Structure Matrices and Domain Mapping Matrices.* International Journal of Project Management 25(3). DOI: 10.1016/j.ijproman.2006.11.003.

Emmerson, Harold (1962) *Survey of Problems Before the Construction Industry.*

Fazio, P., P. Théberge, S. revay, and O. Moselhi (1988) *Design Impact of Construction Fast-Track.* Construction Management and Economics 6(3). DOI: 10.1080/01446198800000018.

Felix T. Uhlik, and Georgina V. Lores (1998) *Assessment of Constructability Practices Among General Contractors.* J. Archit. Eng., 4(3):113–23.

Fischer, Martin, and C. B. Tatum (1997) *Characteristics of Design-Relevant Constructability Knowledge.* Journal of Construction Engineering and Management 123(3). DOI: 10.1061/(asce)0733-9364(1997)123:3(253).

Fisher, Deborah J., Stuart D. Anderson, and Suhel P. Rahman (2000) *Integrating Constructability Tools into Constructability Review Process.* J. Constr. Eng. Manage. 126(2):89–96.

Gugel, John G., and Jeffrey S. Russell (1994) *Model for Constructability Approach Selection.* Journal of Construction Engineering and Management 120(3). DOI: 10.1061/(asce)0733-9364(1994)120:3(509).

Haggard, Rusty (1986) *Constructability - A Primer.* Construction Industry Institute (CII) 3(1).

Huovila, P., L. Koskela, M. Lautanala, K. Pietiläinen, V. P. Tanhuanpää (2010) *Use of the Design Structure Matrix in Construction in Lean Construction.* VTT Building Technology, Espoo, and Finland.

Jadidoleslami, Samereh, Ehsan Saghatforoush, Amirhossein Heravi, and Christopher Preece (2018) *Evaluating the Existing Barriers in Implementing Constructability.* Civil Engineering Journal 4(12). DOI: 10.28991/cej-03091204.

Research paper UGC CARE Listed (Group -I) Journal Volume 11, Iss 12, 2022

O'Connor, James T., Stephen E. Rusch, and Martin J. Schulz (1987) *Constructability Concepts for Engineering and Procurement.* Journal of Construction Engineering and Management 113(2). DOI: 10.1061/(asce)0733-9364(1987)113:2(235).

Paulson, Boyd C. (1976) *Designing to Reduce Construction Costs.* ASCE J. Constr. Div. 102(4). DOI: 10.1061/jcceaz.0000639.

Radtke, Michael W., and Jeffrey S. Russell (1993) *Project-Level Model Process for Implementing Constructability.* Journal of Construction Engineering and Management 119(4). DOI: 10.1061/(asce)0733-9364(1993)119:4(813).

Russell, Jeffrey S., and John G. Gugel (1993) *Comparison of Two Corporate Constructability Programs.* Journal of Construction Engineering and Management 119(4). DOI: 10.1061/(asce)0733-9364(1993)119:4(769).

Russell, Jeffrey S., John G. Gugel, and Michael W. Radtke (1994) *Comparative Analysis of Three Constructability Approaches.* Journal of Construction Engineering and Management 120(1). DOI: 10.1061/(asce)0733-9364(1994)120:1(180).

Sheehan, John M. (1992) *Discussion of Constructability and Constructability Programs:* White Paper by The Construction Management Committee of the ASCE Construction Division (March, 1991, Vol. 117, No. 1). Journal of Construction Engineering and Management 118(2). DOI: 10.1061/(asce)0733-9364(1992)118:2(415.2).

Yassine, Ali A. (2004) *An Introduction to Modeling and Analyzing Complex Product Development Processes Using the Design Structure Matrix (DSM) Method.* Journal Urbana 51(9):1–17.

Zolfagharian, Samaneh, and Javier Irizarry (2017) *Constructability Assessment Model for Commercial Building Designs in the United States.* Journal of Construction Engineering and Management 143(8). DOI: 10.1061/(asce)co.1943-7862.0001323.