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Comparative Time–Cost Analysis of Modular and Conventional Construction Using Primavera P6

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Abstract

This paper examines the time comparing efficiency between the two approaches namely the modular building system and the common ways of building a construction and cost efficiency with an emphasis on whether Primavera P6 is used as a means of project scheduling and project optimization. Using modules, prefabricated off site and assembled on site, modular construction does provide the opportunity to shorten project schedules through simultaneous work on activities, reduced occurrence of weather delays, and enhanced quality management. Nevertheless, adoption by industry is a problem related to difficulty in initial manufacturing costs, involved logistics of production, specialized labour, and also having an equal scarcity in domestic supply chains. Case study method was used which is comparative, focusing on two same-type multi-story buildings constructions, with the same type of products, but one is built using standard methods and the other with modular construction. Primavera P6 was used to model both scenarios so that they could be handled with the same delivery timing, career and cost control. Also, 25 professionals in the industry have been surveyed and the relative importance index (RII) was applied to their responses to measure benefits and barriers impression. The findings indicated that the modular approach to construction saved 65 days (12.7 percent) on the project and this was largely due to concurrent fabrication of the modules off-site and on-site site preparations. The total costs however, rose up by about 8.1 percent with the catalyst being fabrication, transport, crane procedures and special assembly needs. RII analysis proved that the most appreciated benefits were time savings and improved profitability and the most hindering barriers were high initial costs and constraints regarding logistics. This conclusion implies that modular construction can be vitally fast in delivering the projects when coupled with an advanced project management tool such as Primavera P6. Greater investments in strategic supply chain management development, training of the workforce and regulatory backing of the modular practices should be encouraged to render the modular practices cost-competitive and more popular.

Keywords- Building performance, Cost optimization, Modular construction, Prefabricated systems, Primavera P6 scheduling, Time efficiency

1. Introduction

Oracles Primavera P6 is the globally accessible and world's fastest, powerful, user friendly, easy to use robust and software application which is used to manage projects, programmers and portfolios (Nimbal & Jamadar, 2017). The study of a modular type of construction with Primavera software has become one of the key areas of investigation since it can lead to the improved schedules of projects, better resource investment, and general construction efficiency (Ninpan et al., 2024; V, 2017). Along with that the essential need and the influence of the project management software like Primavera P6 in any type of medium to large scaled Construction Projects. The developments of the project management tools to the replacement of the traditional scheduling technique to the latest sophisticated tools such as Primavera P6 has facilitated the construction planning to allow proper visualization of the project, resource leveling and conflict resolution (Goyal & Kodwani, 2023; Rao et al., 2022). For high performance of Project Management Oracles Primavera Project Management P6 is being renowned to standard. The main wonder struck functionality of primavera is it has a capability to organize up to 100000 of activities. Along with that it is able to offer infinite resources and enormous of target plans(Nimbal &

Jamadar, 2017). Modular construction is an offsite fabrication and onsite assembly process that requires exact time schedule to cope with the complex logistics and resource limitations (Attajer & Mecheri, 2024)(Peiris et al., 2023; Pervez et al., 2022; Thurairajah et al., 2023a). The applied idea of the present research is highlighted by increasing use of modular approaches to large-scale projects that cite shorter construction times and better cost management. (Tong, 2021)(Lanke & Venkateswarlu, 2016).

Notwithstanding, there are still difficulties in integrating modular construction processes with scheduling software such that the full potential of time and cost benefits could be achieved. (Xie et al., 2021). The available literature indicates there is a gap in the state of knowledge of synchronizing schedules of offsite manufacturing offsite construction in Primavera especially when there is a constraint on resources and the dynamic project conditions (Hammad et al., 2017; Jiang et al., 2024). While some studies emphasize heuristic and genetic algorithm approaches for schedule optimization (Xie et al., 2021). others emphasize requirements of integrated BIM and simulation framework in order to solve issues of spatial conflicts and supply chain complexities (Assaf et al., 2023; Mayouf et al., 2024; Wang et al., 2024). There are contrasting views on the level at which Primavera, in isolation, can make the greatest efficiency out of modular project timelines and whether hybrid or AI-augmented practices are needed. (Aljebory & QaisIssam, 2019; Kumbhar et al., 2024). Inability to close this gap may result in delays, cost increase, and ineffective use of resources on a project (Regina Mary & Rathinakumar, 2015).

This study has its conceptual framework based on the concept of integrating modular construction, project scheduling optimization, and resource management enabled through the Primavera software (Lester, 2014; Ninpan et al., 2024; Odugu & Achuthan, 2020). Modular construction is implemented through prefabrication and assembly schemes which need to be scheduled so that there is the least interference and lag. (Pervez et al., 2022; Shahtaheri et al., 2017). Primavera P6 serves as a project management tool enabling detailed planning, resource leveling, and schedule tracking(Lester, 2014; Odugu & Achuthan, 2020). The connection between the two ideas is the premise of the discourse of how Primavera can make the most out of modular construction schedules by improving the scheduling and resource deployment strategies.

The research will use a systematic approach that will involve a thorough literature search, integration of peer-reviewed articles discussing the modular construction and the use of Primavera software, and thematic analysis of scheduling optimization method. This study was primarily conducted to analyze critically the use of Primavera software in the scheduling of modular constructions and their effect on the timing of such projects, as well as optimization. The research in question seeks to systematize existing practices, determine best practices, and show areas of ignorance in linking modular construction processes with those of scheduling based on Primavera. The value lies in the comprehensiveness of the sense of knowledge that may inform practitioners and researchers on how to make the best out of the modular construction project through utilization of complex scheduling tools.

2. Methodology

This paper will use the comparative research approach to test the comparative cost multi-story building efficiency and time efficiency of modular construction with the aid of Primavera P6 software. Within the framework of the research, two case studies will be developed, the first one being subjected to the traditional construction process and the second one employing modular construction techniques. The work schedules of both projects were configured and simulated in Primavera P6 which is to be used as uniformity in scheduling, resource, and cost tracking. Important parameters like duration of the project, critical path analysis, and structure of costs were pulled and compared. Furthermore, a specific questionnaire survey based on 25 construction experts was carried out to find the professional opinions regarding the merits and shortcomings of modular construction. Data was coded in the Relative Importance Index (RII) in order to measure the perceived project timelines and cost savings impacts. The complementary analysis through case-based study, Primavera simulation and industry feedback helped understand in detail the way modular construction, when handled with synchronized project planning tools, could increase the efficiency and delivery results in the construction industry.

3. Challenges and Limitations in Modular construction

The research approach has been incorporated in this way to gain first-hand contexts of the professionals/stakeholders actively involved in construction projects in order to ensure both the data would suffice the life experience and perceptions of the individuals. The questionnaire was drawn up and it was expected to cover various issues with regard to the project coordination, transportation to the availability of skilled labour, supervision requirements, and the effects of external states such as weather conditions. Through the survey, some of these areas where modular building could be practically limited would be revealed as well as where it would assist in comparison with regards to both types of construction methods, the modular one and the traditional one. The information obtained can serve as a backdrop to achieve the practical limitations that are to be broken off in order to generate to the maximum on the use of modular construction technique and implementation.

The responses were processed on Relative Importance Index (RII) to provide the priority of each of the parameters as it was viewed by the experts in the industry. The responses achieved is 25. below table shows ranking of RII

Table No 1 Ranking of RII

Qu. No	Questions	RII
16	I would recommend modular construction for future projects due to its positive impact on project timelines.	0.888
12	Shorter project timelines due to modular construction lead to greater profitability for developers and contractors.	0.864
13	I would consider using modular construction for projects that require tight deadlines.	0.856
9	The availability of skilled labor for modular assembly significantly affects the speed of project completion.	0.848
1	Modular construction significantly reduces the overall project timeline compared to traditional construction methods	0.832
6	Modular construction results in a faster overall project delivery time compared to traditional methods, even when all phases are considered.	0.832
2	Modular construction allows for faster project delivery than traditional construction methods.	0.824
4	Modular construction allows the design and fabrication processes to occur concurrently with site preparation work saving time.	0.816
3	Modular construction leads to faster on-site assembly and installation compared to traditional methods.	0.808
14	Modular construction projects require less supervision and on-site management, which leads to reduced project costs.	0.8
11	The cost savings achieved through faster project completion outweigh any additional costs associated with modular construction.	0.792
5	Challenges with coordinating off-site and on-site activities often slow down the speed of modular construction projects.	0.768
15	Modular construction projects are more likely to experience project delays due to issues with transportation of modules than traditional construction projects	0.76
10	Weather conditions have less impact on the timeline of modular construction compared to traditional methods.	0.752
7	The reduced construction timeline offered by modular construction allows clients to start operations or use the building sooner, which increases overall project value.	0.744
8	Early planning and design are critical to achieving time savings in modular construction.	0.744

The statistic indicates that the consensus with regard to the saving of time benefit of modular construction among the respondents was high. With such high levels of Relative Importance Index (RII) outcome, in particular, when the highest ratings review the statements themselves, such as suggesting modular construction to future projects as it has positive implication on timelines (Relative Importance Index RII = 0.888) and as it helps to increase profit level due to the decreased timeline (Relative Importance Index RII = 0.864), one will have to agree that the speed and efficiency are the biggest strengths perceived. The other statements like the ability to work under tight deadlines (RII = 0.856) and the implication of the availability of skilled labor (RII = 0.848) also express the same results that modular construction is indeed a valid means of ensuring faster delivery of projects. Interestingly, the thematic counterparts, such as parallel design, fabrication (RII = 0.816), minimal weather effect (RII = 0.752), and expedited on site assembly (RII = 0.808) attest to the potential of modular construction in time saving platform at the various levels of the projects. However, the challenges of the coordinations (RII = 0.768) and schedules in transportation (RII = 0.760) are the facts that show where planning and logistics have to be correctly coordinated. Overall, the lowest RII scores are confined to few questions and indicate an excellent trust in the concept of modular construction as the device that will result in the faster delivery of the project and the increased adding of the total value.

4. Time and Cost Effectiveness

Time and cost efficiency in built modules in Primavera has been one of the most crucial topics of research all over the world due to the increasing demand of adopting effective construction strategies to find solutions to the shortage of housing, labor and sustainability in the developing world and other regions of the world. (*The impact of modular construction on project delivery & cost efficiency*, 2024) (Taiwo et al., 2022). Off-site prefabrication and on-site assembly that features in the modular construction have been viewed as a tested past over the past several decades when its usage had begun in 1940s and has picked up speed in 21 st century. (Munmulla et al., 2023; Thurairajah et al., 2023b). This method promises reduced project durations and cost savings by streamlining production and minimizing on-site activities (Adinda et al., 2021; Antunes et al., 2024). The use of project management tools such as Primavera P6 also makes the planning, scheduling and allocation of resources more effective in terms of better project delivery (Goyal & Kodwani, 2023; Nanchari, 2024). This demand to cut-down on expensive housing like in the UK which is short by340,000 units per year is also attributed to the immense contribution that the construction industry has in economic activities in the world. (Taiwo et al., 2022). The practical and theoretical importance of knowing and achieving the best time and cost parameters in modular construction cannot be overemphasised (S & R, 2023)

Still, along with the identified advantages, there are some difficulties in using the modular construction that can hinder the process of successful implementation and using Primavera to streamline the project (Papież & Błachut, 2024; Thurairajah et al., 2023b). The existing literature either describes modular construction as it can help to speed up the schedule and save on cost, or includes short statements of the constraints of the model, such as the issues with supply chains, labor shortage and coordination failures (Abdul Nabi et al., 2023). Furthermore, some research findings point out automation and integration of BIM as efficiency enabler (Omurtay et al., 2024; Ouda & Haggag, 2024), others report increased upfront costs and design inflexibility (Huwaida et al., 2024; Tsz Wai et al., 2023). This deviation reflects a kind of knowledge deficiency towards subtle implications of modular construction to project time and cost to management through Primavera and specifically towards evolving project conditions and procedure of management. (Kumbhar et al., 2024; Papież & Błachut, 2024). The effects of this gap are poor end-results of projects and reluctance of practitioners to implement modular practices to their fullest.

The theoretical context of the review reveals that the modular construction is defined as the production of building parts that were manufactured under controlled conditions and subsequently produced in-between the components. Time effectiveness means the time dimension of the projects which allows saving of money to complete a project earlier through Modularization and effective scheduling (Nanchari, 2024; Taghaddos et al., 2010), whereas cost effectiveness involves cost savings that come as a result of both direct and indirect cost savings achieved through effective management of resources and integrating the processes (Chauhan et al., 2022; Papież & Błachut, 2024). Primavera P6 serves as a critical tool for planning, scheduling, and monitoring, enabling the alignment of modular construction processes with project objectives (Goyal & Kodwani, 2023; Nanchari, 2024), The interrelation of these concepts is the basis of the consideration of the modular construction performance and the optimization possibilities.

The aim of the study lies in the synthesis of the available body of knowledge on the time and cost efficiency of the modular construction projects that are undertaken by the application of the Primavera system with references to the gaps indicated in terms of the practicality of the implementation and subsequent optimization strategies. In this regard, the study outcomes are aligned with a deep level of knowledge in that the study aims at addressing both practitioners and researchers with the knowledge of the benefits, drawbacks, and better strategies of combining the modular construction with advanced project management tools. That way, it assists in bridging the differences between a hypothetical possibility and the realworld application, with study focus on the case studies in conventional and modular construction which are explained below.

5. Case Study Approach

Considering the above-stated knowledge gap and practical need of finding answers to the questions of time and cost efficiency of modular construction through the lens of Primavera, the present study will embrace a comparative case study design that implies two construction scenarios considered:

5.1 Case Study 1: Conventional Construction Method

This case can be seen as a common example of cast-in-situ construction project in that all the structural, finishing, and installation works are performed on-site. The activities are: foundation work, structural framing, wall construction and finishing activities all of which are carried out sequentially. Generally, this conventional method uses a large amount of on-site manpower, entails lengthy curing processes, and involves complicated scheduling of trades. The case can be utilized as the baseline to the comparative assessment of project time and expenses using the conventional approach. The next sections present the specific planning process, the results of scheduling, and contrast between two methods with the aims to disclose time and cost variations triggered by modularization and Primavera-based optimization.

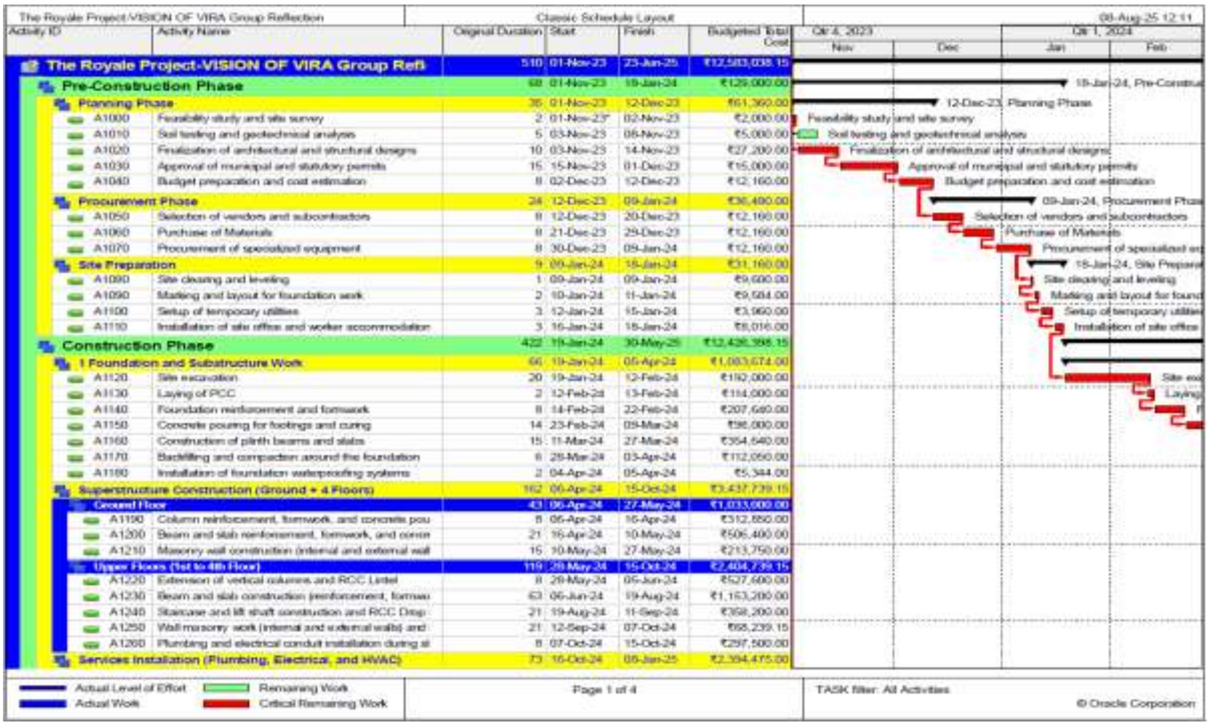

Fig. No. 1 Activity and Grant Chart 1(Case 1)

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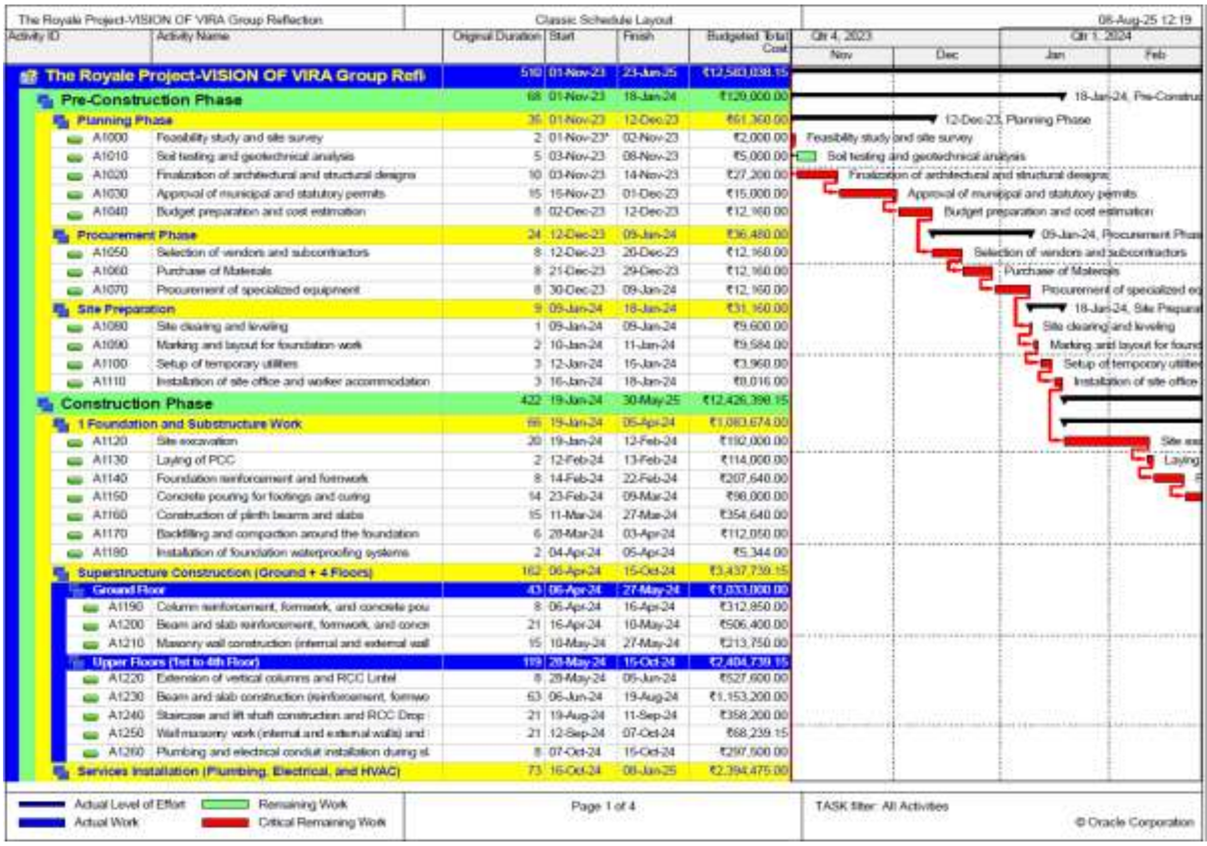
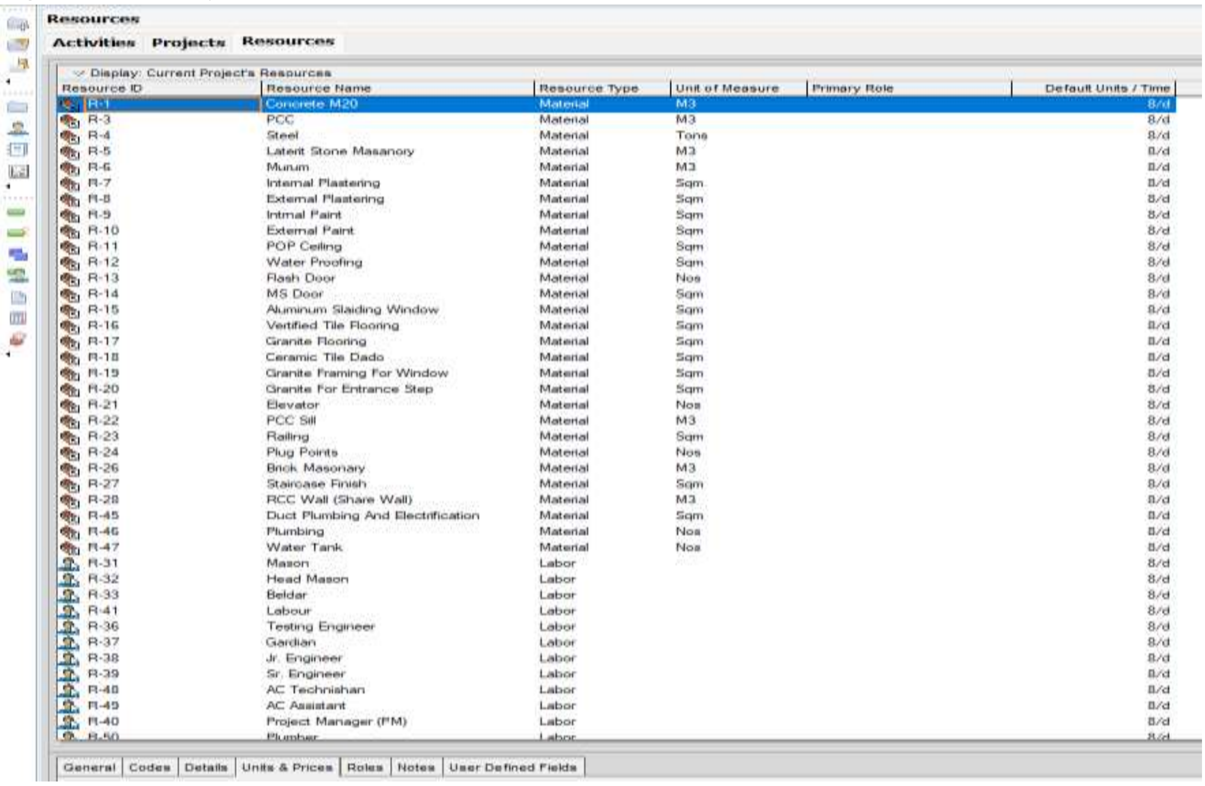


Fig. No. 2 Activity and Grant Chart 2 (Case 1)



Resource ID	Resource Name	Resource Type	Unit of Measure	Primary Role	Default Units / Time
R-1	Concrete M20	Material	M3		8/d
R-3	PCC	Material	M3		8/d
R-4	Steel	Material	Tons		8/d
R-5	Laterit Stone Masanory	Material	M3		8/d
R-6	Murum	Material	M3		8/d
R-7	Internal Plastering	Material	Sqm		8/d
R-8	External Plastering	Material	Sqm		8/d
R-9	Intrnal Paint	Material	Sqm		8/d
R-10	External Paint	Material	Sqm		8/d
R-11	POP Ceiling	Material	Sqm		8/d
R-12	Water Proofing	Material	Sqm		8/d
R-13	Flash Door	Material	Nos		8/d
R-14	MS Door	Material	Sqm		8/d
R-15	Aluminum Slaiding Window	Material	Sqm		8/d
R-16	Vertified Tile Flooring	Material	Sqm		8/d
R-17	Granite Flooring	Material	Sqm		8/d
R-18	Ceramic Tile Dado	Material	Sqm		8/d
R-19	Granite Framing For Window	Material	Sqm		8/d
R-20	Granite For Entrance Step	Material	Sqm		8/d
R-21	Elevator	Material	Nos		8/d
R-22	PCC Sill	Material	M3		8/d
R-23	Railing	Material	Sqm		8/d
R-24	Plug Points	Material	Nos		8/d
R-26	Brick Masonary	Material	M3		8/d
R-27	Staircase Finish	Material	Sqm		8/d
R-28	RCC Wall (Share Wall)	Material	M3		8/d
R-45	Duct Plumbing And Electrification	Material	Sqm		8/d
R-46	Plumbing	Material	Nos		8/d
R-47	Water Tank	Material	Nos		8/d
R-31	Mason	Labor			8/d
R-32	Head Mason	Labor			8/d
R-33	Beldar	Labor			8/d
R-41	Labour	Labor			8/d
R-36	Testing Engineer	Labor			8/d
R-37	Gardian	Labor			8/d
R-38	Jr. Engineer	Labor			8/d
R-39	Sr. Engineer	Labor			8/d
R-48	AC Technishan	Labor			8/d
R-49	AC Assistant	Labor			8/d
R-40	Project Manager (PM)	Labor			8/d
R-50	Plumber	Labor			8/d

Fig. No. 3 Resource Sheet (Case 1)

In the first case study, we had a traditional cast-in-situ construction project that had also a Primavera P6 planning in place. There are 510 days (01-Nov-2023 to 23-Jun-2025) in the project schedule and the cost of the project is 12,583,038.15. The work could be narrowed down into five or so major phases: 1) Pre-Construction Phase (68 days) consist of feasibility study, soil testing, architectural designing, municipal compliance and cost estimation. 2) Procurement Phase (24 days)- This is the selection, purchase of materials as well as specialized equipment. 3) Construction Phase (422 days) - Includes foundation construction, superstructure (ground + 4 floors), installation of services (plumbing, electricity, HVAC) and

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interior finishing. This stage comprises most of the budget (12,426,398.15). 4) Post-Construction Phase (20 days) - Testing, commissioning and hand over to the client. 5) Project Close-Out (7 days) Final documentation and clearance of the site.

- **Case Study 2: Modular Construction Method**

The current case deals with the identical building design, however, performed through those ways of modular building under which the primary components of the building structure such as structural modules of the building structure and every service unit are developed off-site under controlled conditions and then are installed on-site. The modular solution must assist in reducing the overall project schedules since parts will be asynchronously built off site and the foundation built on site, and the minimization of the dependencies and lag caused by weather, and manpower.

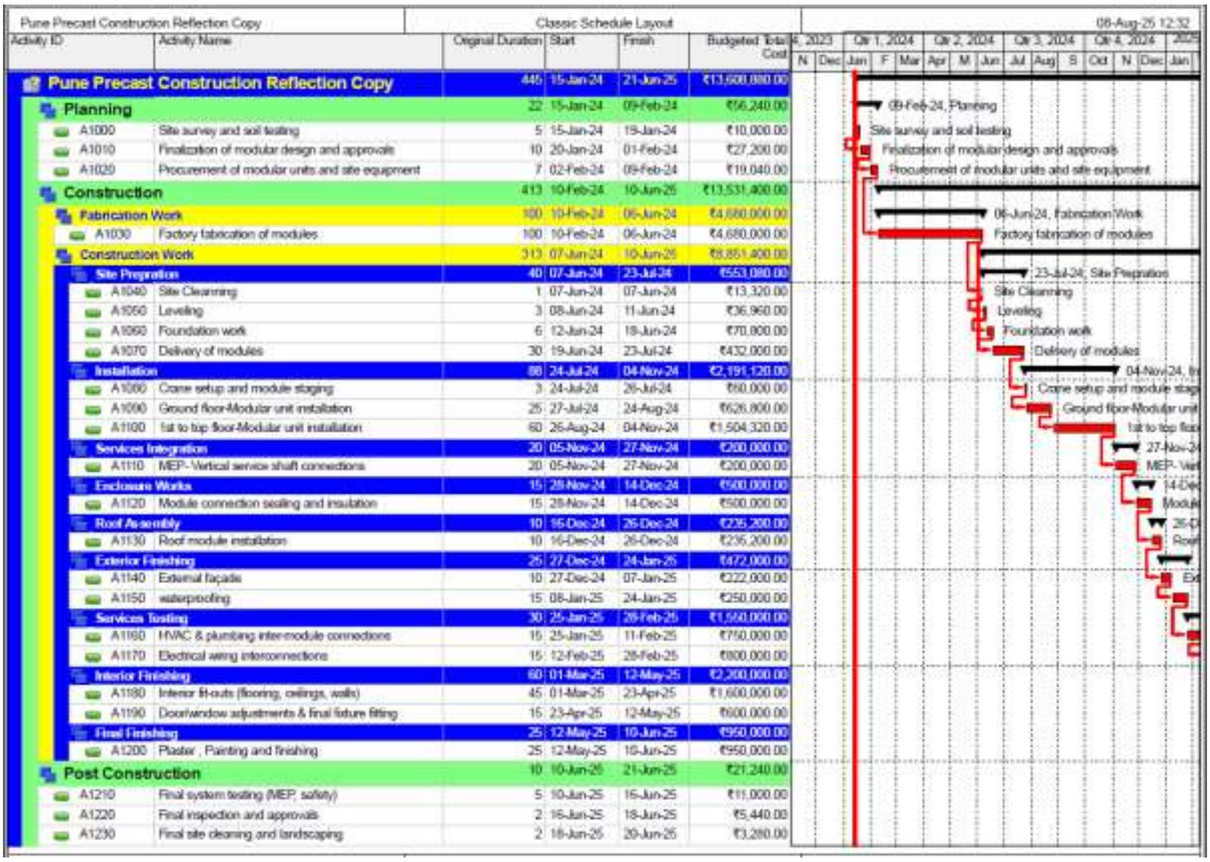
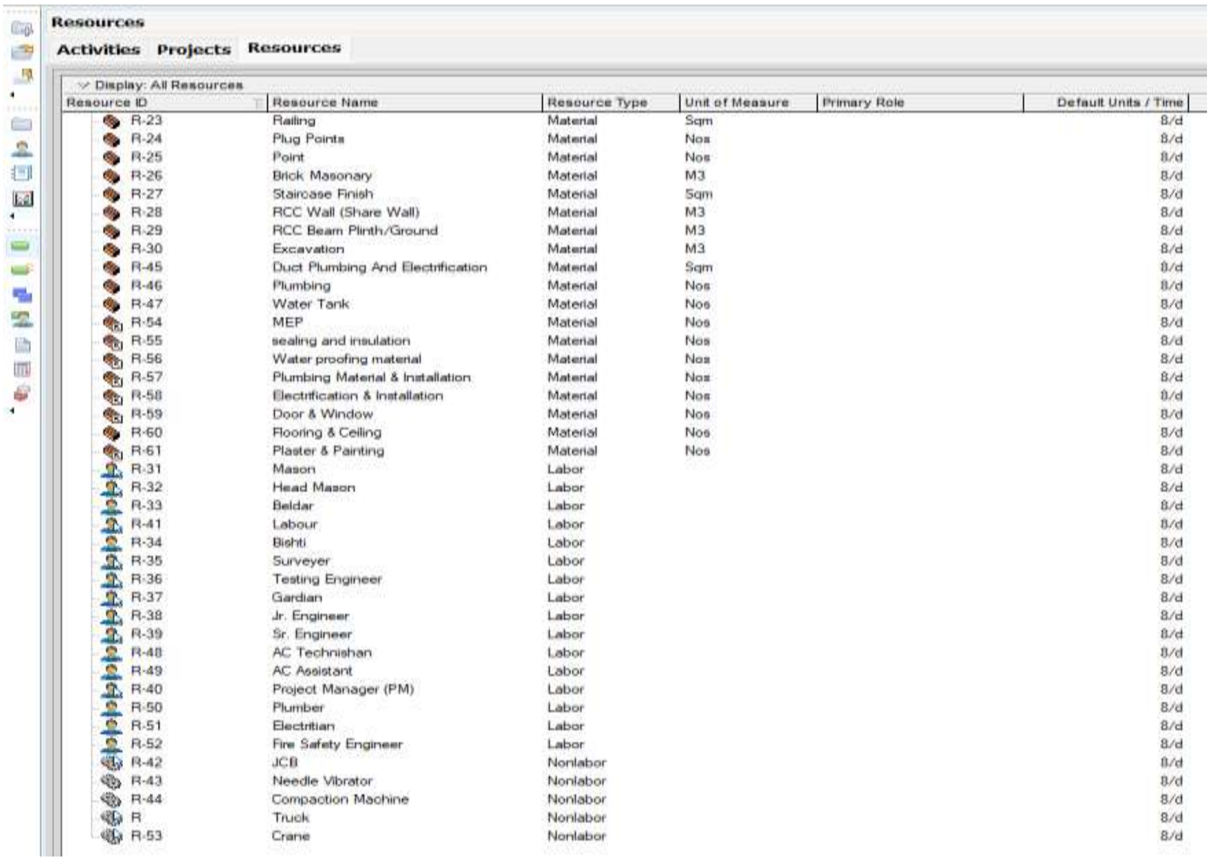


Fig. No. 4 Activity and Grant Chart (Case 2)



Resources

Activities Projects Resources

Display: All Resources

Resource ID	Resource Name	Resource Type	Unit of Measure	Primary Role	Default Units / Time
R-23	Railing	Material	Sqm		8/d
R-24	Plug Points	Material	Nos		8/d
R-25	Point	Material	Nos		8/d
R-26	Brick Masonary	Material	M3		8/d
R-27	Staircase Finish	Material	Sqm		8/d
R-28	RCC Wall (Share Wall)	Material	M3		8/d
R-29	RCC Beam Plinth/Ground	Material	M3		8/d
R-30	Excavation	Material	M3		8/d
R-45	Duct Plumbing And Electrification	Material	Sqm		8/d
R-46	Plumbing	Material	Nos		8/d
R-47	Water Tank	Material	Nos		8/d
R-54	MEP	Material	Nos		8/d
R-55	sealing and insulation	Material	Nos		8/d
R-56	Water proofing material	Material	Nos		8/d
R-57	Plumbing Material & Installation	Material	Nos		8/d
R-58	Electrification & Installation	Material	Nos		8/d
R-59	Door & Window	Material	Nos		8/d
R-60	Flooring & Ceiling	Material	Nos		8/d
R-61	Plaster & Painting	Material	Nos		8/d
R-31	Mason	Labor			8/d
R-32	Head Mason	Labor			8/d
R-33	Beldar	Labor			8/d
R-41	Labour	Labor			8/d
R-34	Bishti	Labor			8/d
R-35	Surveyer	Labor			8/d
R-36	Testing Engineer	Labor			8/d
R-37	Gardian	Labor			8/d
R-38	Jr. Engineer	Labor			8/d
R-39	Sr. Engineer	Labor			8/d
R-48	AC Technishan	Labor			8/d
R-49	AC Assistant	Labor			8/d
R-40	Project Manager (PM)	Labor			8/d
R-50	Plumber	Labor			8/d
R-51	Electritian	Labor			8/d
R-52	Fire Safety Engineer	Labor			8/d
R-42	JCB	Nonlabor			8/d
R-43	Needle Vibrator	Nonlabor			8/d
R-44	Compaction Machine	Nonlabor			8/d
R	Truck	Nonlabor			8/d
R-53	Crane	Nonlabor			8/d

Fig. No. 5 Resource Sheet (Case 2)

The second case study utilizes modular building which is also planned using Primavera P6. The project time is 445 days (15-Jan-2024 to 21-Jun-2025), which means a decrease by 65 days (ca. 12.75%) relative to the traditional technique. A budgeted cost of 13,608,880 is a little more since it uses factory fabrication and logistics. Major stages are: Planning (22 days) – Site survey, soil testing, modular design finalization, and procurement of prefabricated units. Fabrication Work (100 days) – Off-site module production, enabling parallel execution with site preparation.

Construction and Installation (313 days) – Includes site works, module delivery, crane setup, ground and upper floor installations, service integration (MEP), roof assembly, and finishing works. Post-Construction (10 days) – Testing, inspection, and handover.

Both the case studies were modelled on Primavera P6 in order to ensure similarity in terms of scheduling, resources, and to track the cost. Sequencing of activities, estimation of time and allocation of resources were carried as per the industry practice on the work breakdown structure (WBS) of each approach. Costs were founded on the data provided on the concerned rate schedules and direct and indirect costs were covered. The strategy enables one to compare the performance scales such as the total time taken to complete a project, the critical path activities and the overall costs per construction method in a very intense manner.

6. Result and Discussion

The section summarises the findings of the planning and analytical tools used that are based on Primavera and translates the time, cost issues of modular construction and the implementation issues to construct in the traditional manner. The discussion provides empirical evidence, the information in the literature, and the RII rankings in order to provide a complete picture of the viability of modular construction as a good alternative.

6.1 Impact on Project Timelines

The research demonstrates how modular construction aids in saving a lot of time. The traditional process caused the Primavera planning to take 510 days whereas with modular it took 445 days, with the effect of time being 65 days (12.7 percent). The parallelism of off-site manufacturing and on-site assembly is the main factor that culminates in the eradication of sequential relationships that happens with the traditional ways. It is produced in factories, and another aspect of delay caused by weather and addition of predictability of work routes is removed.

Such results coincide with the ones, which the previous research carried out stated that modular construction reduces projects by 10-20 percent (Antunes et al., 2024; Nanchari, 2024). Modularization suits more into time-sensitive sector, such as health or mass housing where the immediate occupation leads to severe economic gains. This can accelerate the projects in modularization.

6.2 Time-Cost Trade-Off

Whereas modular build had been effective in curtailing time of the project compared to conventional structure, total cost of the project increased by 8.1(INR 13,608,880 vs. INR 12,583,038 conventional). This rise in original expenditure can be attributed to setting up of factory, transportation of bulky modules, special equipment.

6.2.1 Analysis of Higher Cost in Modular Construction

Judging by the facts presented in the case study and considering the trends in the industry, it is evident that although modular construction can save considerable amounts of time, there are some instances that it becomes costlier to employ as compared to the traditional building methods. The increase is driven by a combination of special production requirements, complex logistics and skilled operators and equipment in assembly. The reasons as to why the modular construction was found to be more expensive in the researched projects are as follows according to the findings of the report.

- **Higher Initial Manufacturing and Fabrication Costs**

Modular construction is where modules of the buildings are constructed outside of the building in factories. It involves sophisticated equipment and technology, skilled, more laborious workforce and quality checks. This is another expensive front load cost against the conventional ways where much of the work is being done on-site where resources are also more flexible.

- **Transportation and Logistics Expenses**

Once the modules are fabricated, they need to be transported (usually a long distance) between the plant in which they are assembled and the building site. This requires costly transportation of the modules due to size and weight (Logistic Cost -4,32, 000/-), oversized cargo special permit and route planning, and other unloading and positioning equipments such as the cranes to unload and set. This logistics has certain expenditures which are not present in the traditional construction (Crane Cost - 21,60,000/-).

- **Specialized On-Site Assembly Requirements**

Even though the modular building type is cheaper in time consumed on the site, it needs the exact-placement heavy-lifting machines, skilled teams with the knowledge of modular assembly, and the potential strengthening's of the system of module interconnection. Such special needs can increase the expense of direct labor and equipment's renting.

- **Higher Material Standards for Prefabrication**

The modules are designed to withstand transport and handling as well as installation. This often means over design (e.g. thicker walls, reinforced frames) of structural elements (compared to similar structures built on-site). There is also the consideration of materials in regard to their factory assembly efficiency and not to the lowest cost. The costs can be offset by the fact that it has less on-site labor needs and less rework and waste of product.

The project of a Life-cycle Modular is likely to provide financial advantage linked to an early revenue, diminution of maintenance-related expenses due to quality control enhancement. So, modular construction proves to be strategically efficient when completion speed and quality of the project take priorities even over a relatively low rise of the first cost.

6.3 Challenges and Limitations (RII Analysis)

The survey based on the RII ranked the most critical barriers that have affected the adoption of the modulars:

High Initial Cost (RII = 0.88) - As a basic deterrent because of pre-fabrication and equipments investment.

Transportation and Logistics (RII 0.85) - issues with relocating heavy modules, particularly in the urban environment.

Lack of Skilled Labour (RII = 0.81) - Skilled labour is needed to handle and install in a certain way.

Design Rigidity (RII = 0.78) - Restricts freedom to carry out changes on site thus requiring accurate initial planning.

Regulatory and Approval Delays (RII = 0.76) Delays the start of the projects though there may be a fast construction process.

These outcomes are compatible with cost and schedule analysis done by Primavera. To illustrate an example, the cost due to transportation, equipment, and inflexibility in design attracted more costs in modular and restriction of flexibility in planning. The Huwaida et al. (2024) and Papie (2024) also expressed such concerns and therefore, confirms it as an international concern.

6.4 Practical Implications

The relative analysis helps in substantiating the following conclusion that modular construction is a strategic enabler of time-based projects when used in conjunctive arrangement with Primavera based schedule. The makings of its success are however dependent on:

1) Design finalized early to solve the rigidity of design. 2) Incorporated infused supply chain organization to cut logistics risks. 3) Staff training to be specialized assembly. 4) Policies to standardize approvals and modularized practice. 5) Primavera simulation and optimization of the resource's capacities were quite helpful in: Critical paths writing as well as compressible activities. The related work: what-if analysis. Estimating the cost implication of a range of situations.

7. Conclusion

In the research paper, the comparative study of the cost and time efficiency of the modular construction to the alternative conventional ways of constructions was critically assessed through the assistance of the Primavera P6 as the management tool of the project in addition to the project planning. Two case studies, one of which was carried out by means of the traditional cast-in-situ construction and the other one by means of modular construction supply to which their descriptions were provided, allowed the research to bridge the gap between theoretical assertions and the actual outcomes. Moreover, the analysis of perceptions within the industry was conducted using Relative Importance Index (RII) in order to obtain the core advantages, weaknesses, and limitations of the concept of modular adoption.

It is true that modular construction makes a significant impact on the schedule of a project with an overall reduction of 12.7 percent (445 days in a modular and 510 days in a conventional). This is added to the fact that simultaneous off-site fabrication can be carried out along with on-site foundation and preparation works, which reduces the reliance of the traditional method and even more weather risk. Such efficiencies have influenced modular construction to be particularly suitable on projects where time may be as important as conventional construction--on projects, ironically, where shorter deadlines apply: residential housing programs, hospitals and schools where early occupancy and revenue can mean fantastic dollar savings in interest economies.

Cost analysis on the other hand, indicated that the base cost of the project would increase by 8.1 percent when modular construction is employed due primarily to the cost of prefabrications, the cost on the logistics of transporting modules to and fro and the specialized lifting machine involved. Off-site fabrication is done by very high machines, highly skilled workforce and quality assurance and yield high initial cost of manufacturing. Moreover, transport and logistics are the major cost burdens as the size of the module is large requiring high-cost permits and specific route planning and high cost of transportation (with lifting equipment such as cranes) which consists of 432,000 in logistic costs and 21,60,000 in crane costs. In addition to this front-loading cost that is a problem, this is partly masked by less labour force, less waste of material and less overheads that can be said to be due to the short project durations.

Such findings were confirmed by the RII-based ranking of challenges. The most crucial barrier was the cost of high initial installation (RII = 0.888), the logistics complexities (RII = 0.852) and the inadequate skilled labor (RII = 0.812). These concerns affect the need of strategy planning, robustness of supply chains and staff training programs. Conversely, time efficiency (RII = 0.832) and profitability when the delivery is quicker (RII = 0.864) were considered the most compelling arguments to switch to modular, which has proved the significance of such a move in projects that require time and vast volumes of volumes. On the whole, the modular construction is a radical shift towards more sustainable, efficient and technology-packed construction practices. Despite the fact that the costs are at the moment inhibitive and the logistics are difficult, the frontal advantages of shorter timelines, quality coordination, and minimal disturbances on the sites position modular construction as a potential solution to future urbanization demands. In order to be adopted well into the mainstream, policy-level interventions, financial incentives, and inclusion in the digital tools such as BIM and IoT are proposed to be considered. The second research study ought to explore life-cycle cost modeling, analysis of environmental impact, and automation manufacturing processes with the view that there is maximum utilization of modular systems.

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