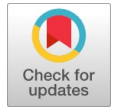


# Workflow Optimization of Material Management Process by Digital Adoption in Indian Residential Projects



Sadhayadharshni C, M. Kranti Kumar

**Abstract:** To analyze the present day's material management process and the extent of digital adoption in the workflow; to identify the shortcomings in the present day's practice; and to formulate digital inclusive framework to manage materials. Objectives 1 & 2 is achieved through 3 step process – Literature review to identify the related shortcomings (factors) and online/ web search to explore available technology; Survey(s) to assess the real time status on the factors, to identify more practical difficulties and the extent of digital adoption in the workflow; Interviewing seasoned professions to gather data in detail concerning material. Objective 3 is achieved by comparison and analysis of the findings. Validation of the framework to assess the potential effects – Partial validation is performed as part of this study. The workflow involved in construction material management is optimised through a framework. Autodesk Revit, MS Project, and MS Access are the three platforms proposed to be part of the framework that suits every phase of the process, including Quantity Survey and Estimation, Procurement Planning, Inventory, Purchasing, and Store Management. Partial framework - MS Project has been validated, and the results are as follows: Ability to map data efficiently; Precise budget and material requirement identification resulted in a 1% cost increase in the overall project budget; Easy cross-verification; Easy documentation; Data-driven decision-making; Multi-dimensional data visibility. Studies in the past have emphasised the benefits of digitalisation and the willingness of the construction sector to adopt it. Studies from 2019, 2020, and 2021 have explored individual digital platforms, such as MSP, Primavera, and Revit, in terms of the part functions involved in material management. However, no study establishes the workflow order between these platforms for complete material management. Additionally, past studies have failed to identify and address the shortcomings related to digital adoption. Hence, this study proposes a framework that determines the order of the workflow involved in material management between these digital platforms to optimise the workflow.

**Keywords:** Material Management, Digital Adoption, MS Project, Residential Developments

## I. INTRODUCTION

Building materials differ from manufacturing materials in that they are more varied, less uniform, and less standardized as well as having different demand characteristics. At every stage of the MM process, material planning and scheduling should be

understood [1]. Decreases in productivity and financial losses were usually attributed to a lack of the supply and flow of construction materials. To minimise the detrimental impacts of a material shortage or excessive material inventory on site, material acquisition and storage on construction sites must be carefully planned and implemented. Management system ensures that the right kind and amount of supplies are correctly chosen, efficiently acquired, dutifully delivered, and securely handled on site in a timely way and at a proper, affordable cost [2].

The construction sector is currently very interested in digitalisation, which is supported by the large number of ICT solutions that have been created. BIM, digital meetings, and web-based project platforms have all been around for a while [3]. Although digitalisation was proposed as a solution and various ICT systems are available, the degree of implementation is scarce. Organizational culture is also a significant factor in preventing its stakeholders from discovering the true potential of digitalization [10]. To enable greater digitization and the efficacy of digital technologies, it is vital to reengineer and digitally convert processes in construction projects and organizations [4]. Primavera and Microsoft Project (MSP) are the predominantly used project management software. Primavera P6 is more efficient with its features, assists in better tracking, is less time-consuming, and requires less paperwork than the conventional method [5]. Like Oracle Primavera, MSP is a contemporary digital tool for project management. Resources can be well-defined (Work, Material and Cost), and can be shared among projects. Scheduled works are executed depending on the availability of resources as predefined in the resource calendar. Being a Microsoft product, it is user-friendly compared to primavera [6]. According to a recent study's inventory analysis, it can be concluded that controlling inventory is highly effective in managing the cost of any construction project. Using MS Project increases the efficiency in the management of inventory by saving cost and time [7]. Resource-loaded schedules are considered the foundation for better planning and offer essential insights into the projected financial success of projects. Nonetheless, most schedules are not resource-loaded. Due to a lack of information, most project managers struggle to create realistic plans. Resource loading can be done using both Primavera and MSP, but the steps involved in loading resources vary. MSP is relatively straightforward to use and extract the required insights. Also, Primavera is a relatively expensive tool. On the other hand, MSP is more affordable and accessible to a wide range of users [9].

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# Workflow Optimization of Material Management Process by Digital Adoption in Indian Residential Projects

Using a BIM tool, such as Revit, with a complete and detailed 3D model of the building, accurate quantities can be derived quickly and efficiently. Mapping back the quantities concerning building is a much simpler task. Also, change management happens efficiently because, with modification in the model, quantities get updated automatically [9]. To explore horizons further, a survey was conducted to track the user's perspective of BIM in managing inventory, and 63.6% of respondents believed that BIM-based inventory management will give effective outcomes beneficial to the Indian construction industry [0]. Followed by that, a case study attempted to mimic a 5D BIM process by combining several information dimensions, such as time scheduling and cost estimation, with a 3D model. To assess the benefits, viability, and constraints of the applications. The process involved six stages, including quantification and cost estimation. The findings concluded that the modelling effort, interoperability, information output, and constraints had an impact on the extent of practicality of 5D BIM. On the other hand, the study also demonstrated that 5D BIM considerably decreased the technical barrier for customers to engage in construction projects, boosting the clients' happiness with the works by bridging the gap between clients' perceptions and the real results of the construction [8].

The studies so far have failed to provide details such as the predominantly used digital technologies in managing materials, the phases at which utilisation is being done, and the Shortcomings in the utilisation of digital technologies. These details are essential for defining the present-day MM process and the extent of digital adoption. Additionally, regarding MM, although numerous digital technologies are available, no framework or procedures have been established to correlate with the process, thereby eliminating the shortcomings of digital adoption. Hence, this study aims to formulate a digitally inclusive framework to optimise the workflow involved in MM. Successful workflow optimisation will decrease expenses, reduce the likelihood of errors, and decrease the time required to complete tasks. The most apparent advantages of workflow optimisation include increased productivity and efficiency, enhanced customer connections, data-driven decision-making, and improved team visibility. A good process can also lessen human error.

## II. MATERIAL MANAGEMENT - INDIAN SCENARIO

A review of most Indian-based studies, primarily focusing on material management across various typologies, was conducted to ensure the relevance of this study.

**Table I: Factors Identified from Literature**

Year	Context	Project Type	Factors - Shortcomings in MM
2013	Gujarat, India	Residential	Delay in Material Delivery
2015	India	Generic	Poor material handling No proper system of material procurement
2017	India	Residential	"Shortage of construction materials in the market and Improper scheduling"
2018	India	Residential	Shortage of materials on site Poor procurement planning
2019	India	Generic	Shortage of materials

2019	Urban region, India	Residential – Small & Medium scale	1) Material planning stage – Poorly defined roles and responsibilities, material stores located far away from the site and poor store layout. 2) "Vendor analysis" stage - Poor communication and coordination between the building contractor and the vendor/supplier 3) "Material purchasing" stage Local issues leading to delays and the unavailability of materials 4) "Storage & inventory" stage Lack of access to contemporary tools and techniques for handling 5) "Supply & distribution" stage Damage to the material on site and a lack of onsite material control
2021	Case study – LMT Tools Ltd., Pune	Industrial building by SCON	Deviation in quantities due to the unavailability of RCC Design drawings Unavailability of material
2022	Somalia	Generic Small and Medium. scale	Shortage of materials during construction. Material cost fluctuation Delayed delivery of materials Over-ordering of materials Material usage without systematic control Difference in material specifications during construction. Theft of materials from the site. Insufficient storage space Use of faulty materials Poor use of advanced software

Shortcomings in MM (factors) identified over the past 10 years of literature are listed in the table above, and these are inferred through a standard research methodology. Additionally, every study is limited to a specific region. These factors are categorised into four different phases involved in MM: procurement planning, purchasing, inventory and storage, supply, and distribution on-site.

**Table II: Factors Categorization – Literature Based**

<b>Procurement planning</b>	Poor procurement planning
	No proper system of material procurement
	Poorly defined roles and responsibilities
	Deviation in quantities due to the unavailability of drawings
	Poor use of advanced software
<b>Purchasing</b>	Poor coordination & communication between the contractor and the material supplier
	Material cost fluctuation
	Delay or unavailability of materials due to local issues
<b>Inventory and storage</b>	"Storage of materials far away from the site, Poor store layout, insufficient storage space"
	"Lack of availability of modern equipment and methods for handling"
<b>Supply and distribution</b>	Shortage & unavailability of materials
	Deviation in material specification during construction
	"Lack of onsite material control"
	Damage to the material on site
	Theft of materials from the site. Delay in material delivery

### A. Confining the Region of Study

Demand for residential properties has surged due to increased urbanization and rising household income. India is among the top 10 housing



markets globally that appreciate in value.

Especially, the recent surge in demand is towards the luxury segment, with a preference for ready-to-move-in homes.

Q1 Y2022 witnessed significant momentum in residential real estate activity. Despite the temporary pause due to the COVID-19 pandemic, new launches across the seven cities have seen a 43% yearly rise compared to Q1 Y2021. Out of which, MMR and Hyderabad account for 51% of total launches in top cities; individually, they see a 59% and 71% yearly rise, respectively. New launches across the top 7 towns saw Hyderabad witness the highest number of new launches in the premium segment. Hyderabad is the only city to have the highest volume of new launches in the premium segment amongst all the top 7 cities, comprising a total share of 54% within the city's overall new supply.

### III. RESEARCH METHODOLOGY

The methodology was developed after a thorough review of the literature and is modelled according to this study, as shown in the figure below, to achieve the set objectives.

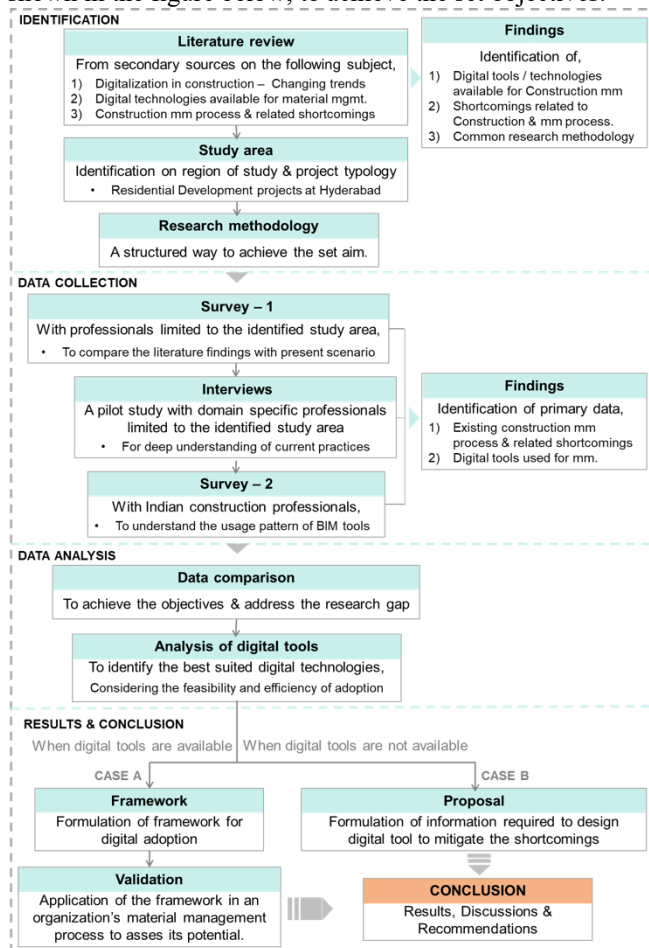


Figure 1: Research Methodology

**Objective 1 and 2 are achieved through a three-step process. The first step involves a literature review of decade-old journals, articles, research papers, books, and theses to understand the background, status of research, and shortcomings in MM (factors). Additionally, digital tools available in the market concerning MM are explored through web or online searches. Next is a survey(s) to assess the real-time status of the factors identified from the literature and to identify more real-time practical shortcomings and the**

extent of digital adoption in the workflow. Because few of the factors mentioned in the literature have been rectified, and some weaknesses of conventional practice may still need to be addressed in the literature. The final step is to interview experienced professionals in the related domain (e.g., Project Manager, Planning Manager, Store Manager, Procurement Manager) to gain a deeper understanding of the current scenario and gather detailed data on the shortcomings concerning materials.

**Objective 3** is achieved through the comparison and analysis of the findings from the previous steps of action. Considering real-time concerns and constraints, a framework must be formulated to mitigate the shortcomings of the available digital solutions (Tools/Software). If any weaknesses cannot be addressed with digital solutions available on the market, proposals must be made. Finally, to validate the developed framework, we assess its potential effects. Thus, the study concludes with the results of the validation, recommendations, and a discussion of future scope.

### IV. DATA COLLECTION

#### Survey 1

**Intention** – To verify the inference from literature with the current practice and to understand the present scenario about digital adoption in material management.

**Target Respondents** – Construction professionals currently practising in Hyderabad.

**Structure** –

1. Profile
2. Level of Agreement on the optimistic statements
3. Frequency of occurrence of the common issues identified through the literature
4. Questions related to digital adoption that will help in addressing the gap identified from the literature

#### Interview

**Intention** – To detail out the areas of concern identified from the survey & literature concerning each material.

**Target Respondents** – Professionals of residential development projects in Hyderabad

**Structure** – Construction materials were listed in categories, and for every item, details like,

1. Source, aspects of procurement planning, risk, inventory planning, storage, wastage percentage and associated indirect cost
2. Percentage deviation observed in terms of cost and quantities
3. Efficient mode of handling within the site
4. Quality-related issues post-construction and those related to software usage were also recorded.

#### Survey 2

**Intention** – To assess the usage of BIM in the Indian construction industry.

**Target Respondents** – Indian Construction professionals

**Structure** – Information on

1. Profile – Role & Location
2. BIM tool used
3. Phases of usage
4. Efficiency of BIM



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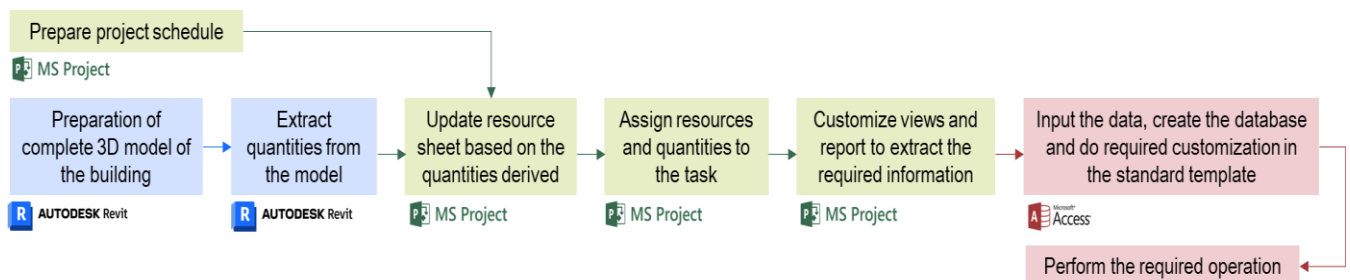
## V. FORMULATION OF FRAMEWORK

Upon analysing the findings from the literature and data collection regarding digital adoption and users' perceptions, the framework should be simple, practical, and efficient. Considering the identified constraints, digital technologies and software are proposed for the various phases of activities involved in the MM process.

As mentioned earlier, digital adoption is leveraging the available digital tools—the consideration of identified shortcomings led to a re-examination of the features and capabilities of the existing software. Similarly, the proposed framework utilizes the digital tools that are already in practice.

**Table VI: Proposal**

Digital Tool	Phase of Utilization	Outcome	Benefits of Adoption	Status	Remarks
Autodesk Revit	Quantity Survey and Estimation	1. Quantities of each material in a tabular form.	Accuracy, ability to map easily, and efficient change management	Proposal only. Efficiency is proven already [0]	Survey 2 aided in understanding the most prevalent BIM tool, Revit, for designing and 3D visualisation. A detailed model would be beneficial for this purpose.
Microsoft Project	Procurement Planning	1. Resource loaded schedule 2. Month/ (customizable) wise requirement of each material in the form of a graph 3. Resource form	A user-friendly interface, simple data input and import, and customisable reports assist in decision-making.	Proposed and validated using actual data of a project that falls within the defined scope of study.	Resource loading can be done in both the PM software; however, the steps involved in MSP are much easier to adapt. Organisations prefer MSP due to its user-friendly interface, which was identified during interactions with project management professionals.
Microsoft Access	Inventory, Purchasing and Store Management	1. Inventory list with rates 2. Vendor contact details 3. Stock control - items being stocked, their current stock levels, and tracking movements into and out of stock 4. Generation of PO & invoices	Economical and multiple tasking (able to do work similar to an ERP).	Proposal only, as the validation requires an operational-level application.	MSA is a part of Microsoft 365 - one of the basic, mandatory tools that every user has installed on their personal computers or laptops. It is a database management system (DBMS) to help businesses manage their work.



**Figure 2: Digital Inclusive Framework**

## VI. VALIDATION OF PARTIAL FRAMEWORK - MSP

Actual data from a project that falls within the defined scope of the study are used for the application and validation of the proposed framework. A resource-loaded schedule of a high-rise residential development project is prepared using MSP. Procedure as follows:

1. Prepare a project schedule using MSP (which is part of the current practice).
2. In the view “Resource sheet”, upload the materials, unit, and unit price.
3. Assign resources to each task. Multiple resources can be assigned to the same task. The quantity of material required for each task can also be uploaded in the same step.

4. As the tasks are displayed in greater numbers, the “Resource usage” quantities can be uploaded.
5. Also, the option “Details” can be chosen to split the window into two. By clicking on the task, the details will be displayed below, and quantities can be entered there.
6. After uploading the relevant information, reports can be customized and generated as shown in the figure below.
7. As a result, the monthly requirement of each material can be extracted in the form of a graph.
8. Adding necessary columns to the resource sheet, as shown in Table VII, will produce a draft BOQ of the project.

The resource sheet serves as the database for assigning resources (materials) to tasks. Column – “Cost” is auto-generated based on the inputs fed into all the other columns.

Table VII (a): Resource Sheet Generated in MSP – Resource Sheet View

Resource Name	Type	Material Label	Initials	Standard Rate	Work	Cost
Site Levelling	Material	Sq.m	S	₹28.15	5,434 Sq.m	₹152,967.10
Resurveying And Marking Site Boundary	Material	LS	R	₹14.00	5,434 LS	₹76,076.00
Site barricading	Material	meter	S	₹2,827.40	2,827.4 meter	₹7,994,190.76
Sample Pile test, vertical load test	Material	LS	s	₹250,000.00	1 LS	₹250,000.00
Excavation	Material	Cu.m	E	₹286.85	273 Cu.m	₹78,310.05
Pile Casting 500mm dia	Material	meter	P	₹2,876.29	4,665 meter	₹13,417,892.85
Pile Casting 600mm dia	Material	meter	P	₹3,662.15	2,257.5 meter	₹8,267,303.63
pile test integrity test	Material	each	p	₹708.00	322 each	₹2,27,976.00

Table VII (b): Resource Sheet Generated in MSP – Resource Sheet View

Resource Name	Type	Material Label	Initials	Standard Rate	Work	Cost
Backfilling	Material	Cu.m	B	₹253.95	2,151 Cu.m	₹546,246.45
PCC	Material	Cu.m	P	₹5,660.45	354 Cu.m	₹2,003,799.30
Concrete M30 till plinth	Material	Cu.m	C	₹8,599.35	960 Cu.m	₹8,255,376.00
Concrete M30 stilt - 5 floors	Material	Cu.m	C	₹10,221.70	3,942 Cu.m	₹40,293,941.40
Concrete M30 6-9	Material	Cu.m	C	₹10,502.65	1,936 Cu.m	₹20,333,130.40
Concrete M30 10-terrace/ohts	Material	Cu.m	C	₹10,783.60	1,092 Cu.m	₹11,775,691.20
Shuttering - RW/CO	Material	Sq.m	S	₹804.20	20,333 Sq.m	₹16,351,798.60
Shuttering - PC	Material	Sq.m	S	₹307.95	676 Sq.m	₹208,174.20
Shuttering - SRS	Material	Sq.m	S	₹766.55	7,869 Sq.m	₹6,031,981.95
Shuttering - TRS/SW/OHT	Material	Sq.m	S	₹608.35	32,867 Sq.m	₹19,994,639.45
Reinforcement	Material	Quintal	R	₹8,966.15	9,130 Quintal	₹81,860,949.50
Masonry up to 5 floors	Material	Cu.m	M	₹6,994.16	1,818 Cu.m	₹12,715,382.88
Masonry 6-9 flrs	Material	Cu.m	M	₹7,136.16	1,456 Cu.m	₹10,390,248.96
Masonry 10-terrace	Material	Cu.m	M	₹7,278.16	825 Cu.m	₹6,004,482.00
Plastering Interior	Material	Sq.m	P	₹374.15	47,300 Sq.m	₹17,697,295.00
Plastering the Exterior up to the 2nd floor	Material	Sq.m	P	₹386.55	8,752 Sq.m	₹3,383,085.60
Plastering the Exterior 4th floor	Material	Sq.m	P	₹532.15	2,838 Sq.m	₹1,510,241.70
Plastering the Exterior 5th floor	Material	Sq.m	P	₹604.95	2,838 Sq.m	₹1,716,848.10
Plastering the Exterior 6th floor	Material	Sq.m	P	₹677.75	2,838 Sq.m	₹1,923,454.50
Plastering the Exterior 7th floor	Material	Sq.m	P	₹750.55	2,838 Sq.m	₹2,130,060.90
Plastering the Exterior 8th floor	Material	Sq.m	P	₹823.35	2,838 Sq.m	₹2,336,667.30
Plastering the Exterior 9th floor	Material	Sq.m	P	₹896.15	2,838 Sq.m	₹2,543,273.70
Plastering the Exterior 10th floor	Material	Sq.m	P	₹968.95	2,838 Sq.m	₹2,749,880.10
Plastering the Exterior 11th floor	Material	Sq.m	P	₹1,041.75	2,838 Sq.m	₹2,956,486.50
Plastering Exterior Terrace	Material	Sq.m	P	₹1,114.54	1,237 Sq.m	₹1,378,685.98
Waterproofing T&S	Material	Sq.m	W	₹406.24	186 Sq.m	₹75,560.64
Waterproofing	Material	Sq.m	W	₹516.62	2,662 Sq.m	₹1,375,242.44
Terrace weathering	Material	Sq.m	T	₹1,522.95	1,888 Sq.m	₹2,875,329.60
Granite Flooring	Material	Sq.m	G	₹2,677.90	2,261 Sq.m	₹6,054,731.90
Floor Tiling	Material	Sq.m	F	₹1,359.20	11,652 Sq.m	₹15,837,398.40
Anti-skid Flooring	Material	Sq.m	A	₹1,311.05	3,362 Sq.m	₹4,407,750.10
Skirting Tiles	Material	Sq.m	S	₹1,466.50	2,424 Sq.m	₹3,554,796.00
Granite Skirting / Dadoing	Material	Sq.m	G	₹3,105.50	720 Sq.m	₹2,235,960.00
Tile Dadoing	Material	Sq.m	T	₹1,063.00	9,632 Sq.m	₹10,238,816.00
Granite Counter	Material	Sq.m	G	₹418.85	330 Sq.m	₹138,220.50
Cutting in Granite Counter	Material	Each	C	₹808.15	132 each	₹106,675.80
Painting - AB Ext.	Material	Sq.m	P	₹166.86	25,928 Sq.m	₹4,326,346.08
Painting - AB Int.	Material	Sq.m	P	₹121.54	31,069 Sq.m	₹3,776,126.26
Painting - C Ext.	Material	Sq.m	P	₹168.00	1,218.11 Sq.m	₹204,642.48
Painting - C Int.	Material	Sq.m	P	₹145.00	16,236.96 Sq.m	₹2,354,359.20
Conduits	Material	meter	C	₹90.00	27,960 meter	₹2,516,400.00
Wiring	Material	meter	W	₹146.00	0 meter	₹0.00
Fixtures	Material	Each	F	₹57.38	0 each	₹0.00
Switches & Sockets	Material	Each	S	₹98.25	0 each	₹0.00
Precast lintel beams	Material	Cu.m	P	₹13,581.00	33.78 Cu.m	₹458,766.18

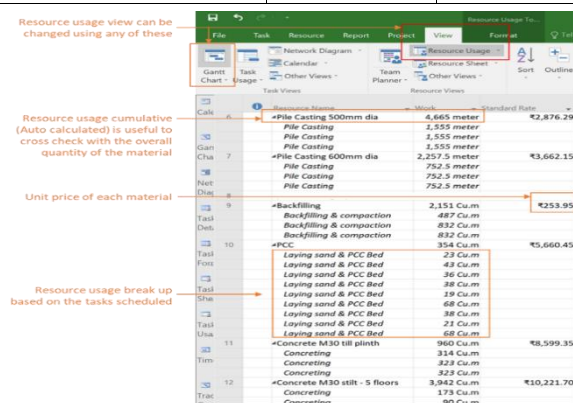
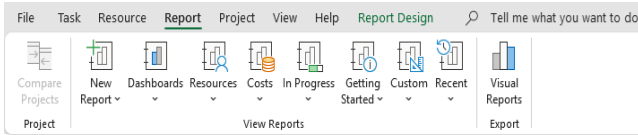


Figure 3: Resource Usage View in MSP

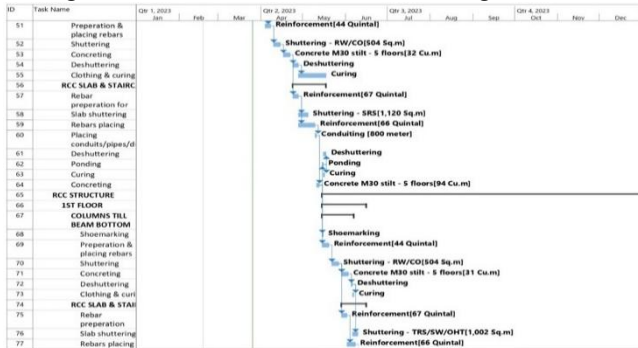
There are multiple ways to assign quantities to the resources. One such is the resource usage view. Aggregate quantities are automatically calculated and will be helpful in cross-verifying with the amounts in the Bill of Quantities (BOQ). Options from the Reports tab will help generate the required data in the form of customisable reports. Each material required per month is extracted as a report in the form of a graph, which will be highly helpful in analysing inventory requirements and planning accordingly.

# Workflow Optimization of Material Management Process by Digital Adoption in Indian Residential Projects

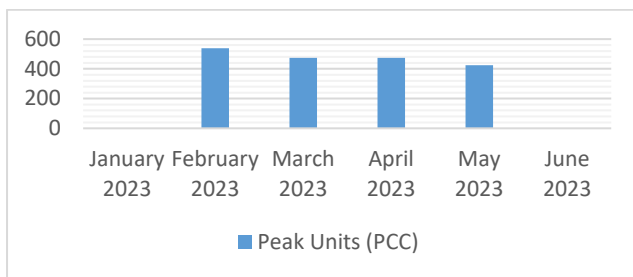


**Figure 4: Reports Tab – MSP**

The resource-loaded schedule is a product of the resource loading that aids in informed decision-making.



**Figure 5: “Resource loaded Schedule” view in MSP**



**Figure 6: PCC Required Per Month in Cu. m**

Here is the report generated from the MSP in the form of a graph, showing the material requirements for each month. Peak units – Aggregate of material required for the tasks assigned in that month. Additionally, this provides insight into the number of months a particular material might require. By the end of those particular months, if the material is still in inventory, it can be tracked as either inefficient inventory planning that results in excess or as a task requiring that material that is still pending, indicating a delay in the schedule. Similarly, graphs have been generated for every material.

## VII. RESULT AND DISCUSSION

### A. Comparison of Gathered Data Against the Baseline

**Objective 1:** To understand the present-day's MM process and the extent of digital adoption in the workflow.

**Table III: Present-day Process and the Digital Tools Used**

Phase	Present-day mm process identified through survey & interviews	Digital tool / Software used
Procurement planning	Project durations – Schedule preparation considering productivity – Procurement schedules are back calculated	MSP / Primavera for project scheduling. Excel for other iterations.
	The planning team will be performing, and the name of the team may vary depending on the organisation, but the roles and responsibilities remain similar.	Team communication is primarily through ERP; some have in-house systems, while others outsource.
	Concerning developer(s), the procurement planning	

	team is in-house with some organisations, and it is left to the contractor in some cases, by providing the project schedule alone.	
Purchasing	Vendor discussions / Negotiations – Personal	E-mails for communications
	Indent from the site is raised, and PO, PR are through vouchers that have been signed by the planning team for approval and progress.	ERP will be used to record all these.
	The majority of items in shell and core, as well as finishing materials such as tiles and paint, are procured in large quantities. Except for interior materials like false ceiling, drywall partitions are procured when needed.	
Inventory and storage	Ageing analysis for materials in storage.	Excel and Google Sheets are used for most iterations, and storage reports are generated from the ERP.
	Reconciliation: Material In + Material Out = Consumption + Wastage	
	Concerning developer inventory planning and storage maintenance, some organisations handle it in-house, while others leave it to contractors.	
Supply and distribution	Storage issues, in terms of space availability, are sporadic, but issues related to theft and poor handling do exist.	
	Lack of onsite material control is prevalent only for supplies.	
	Damage to materials on site is often prone to occur with tiles and pavements. Theft happens with wiring.	

**Objective 2:** To identify the shortcomings in the present-day practice

Ex – Existence Frequency. – Frequency

**Table V: Shortcomings in the Present-Day Practice**

Phase	Shortcomings Identified through Literature	Survey Findings		Interview
		Ex	Frequent	Concerned Material
Procurement planning	Poor procurement planning	-	-	-
	No proper system of material procurement	-	-	-
	Poorly defined roles and responsibilities	-	-	-
	Deviation in quantities and Cost	✓	Often	Structural steel, electrical & plumbing items, Pavements, Cement
	Poor use of advanced software			Excel/ Sheets and ERP are the software used
Purchasing	Poor coordination & communication between the contractor and the material supplier	✓	Sometime	Varies
	Material cost fluctuation	✓	Often	Steel
	Delay/unavailability of materials due to local issues	✓	Sometime	M/s Railings, varies, sand (was)
Inventory and storage	Storage of materials far away from the site, Poor store layout, and insufficient storage space	✓	Sometime	Aggregates, Tiles, Steel, Pumps, Sanitary fixtures, Lifts, HVAC items
	Lack of availability of modern equipment and methods			Largely dependent on Excel for most of the calculations.



Supply and distribution	Shortage and unavailability of materials	✓	Rare	Varies
	Deviation in material specification during construction	-	Rare	Varies
	Lack of onsite material control	✓	Sometime	Minor supplies
	Damage to the material on site	✓	Often	Tiles
	Theft of materials from the site.	✓	Sometime	Wiring
	Delay in material delivery	✓	Sometime	Varies

- 1) 5-10% of material wastage is observed in – Pavements, stone, tiles, Electrical and plumbing items, Steel. Whereas wastage in other materials is between 2% and 3%
- 2) Indirect costs associated with these materials are 10% and above – Mivan, lifts, Tiles, Fabrications, Steel. At the same time, indirect costs associated with other materials are within 3-5%.
- 3) Post-construction quality issues are often found in flooring and services, especially related to plumbing
- 4) Procurement planning Method and tools – Reverse calculation; Excel

#### B. Addressing the Gap Identified from Literature Review

- 1) List of predominantly used digital technologies – MSP / Primavera, MS Excel, ERP
- 2) Phases at which utilisation has been done – Procurement Planning, Purchasing, Reconciliation, Storage
- 3) Weather digital technologies cater for the intended process. – Yes
- 4) **Shortcomings in Utilization of Digital Technologies?**
  - a. Apart from buying, high costs are associated with yearly subscriptions and renewals.
  - b. Server / network issues in using cloud-based software due to the location of the construction site and the unavailability of a network. This makes it difficult to upload or download the required data.
  - c. Information support is weak in such a situation.
  - d. There are too many steps involved in entering the data, and it is difficult to edit the data once entered.
  - e. Data storage costs are high nowadays.
  - f. Relying on an additional tech person to check for errors and maintenance issues increases the unwanted downtime.
  - g. Despite numerous software options available, in India, management continues to rely on physical approval and signatures. These manually created vouchers and documents are photographed and digitally documented, which is also part of the digital adoption identified in the survey.

**Table VIII: Framework Vs. Shortcomings**

Benefits of the adoption of the framework	Mitigates the Shortcomings related to the MM process	Mitigates the Shortcomings in digital adoption
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Makes the procurement planning process composed and structured.	<b>Procurement Planning</b> - Poor procurement planning, No proper system of material procurement, Poorly defined roles and responsibilities, Deviation in quantities and Cost, Poor use of advanced software	Apart from buying, there are high costs associated with yearly subscriptions and renewals. Server/network issues can occur when using cloud-based software due to the location of the construction site and network unavailability, which makes it difficult to upload or download the required data. Information support is weak in such a situation. There are too many steps involved in entering the data, and editing the data once it is entered is difficult. Data storage costs are high nowadays . Relying on an additional tech person to check for errors and maintenance issues increases the unwanted downtime.
Establishes coordination between the project schedule and the required materials, in appropriate quantities, along with their associated costs, facilitating informed decision-making.	<b>Purchasing</b> – Poor coordination & communication between the contractor and the material supplier, Material cost fluctuation, Delay/unavailability of materials due to local issues	
Helps identify the periodic requirements of materials in a well-advanced stage and assists in establishing an inventory and storage control accordingly.	<b>Inventory &amp; storage</b> – Poor store layout, insufficient storage space, Lack of availability of modern equipment and methods <b>Supply and distribution</b> - Shortage and unavailability of materials, Deviation in material specification during construction, Lack of onsite material control, Damage to material on site & Theft.	

#### VIII. CONCLUSION

This study aimed to propose a digital, inclusive framework for a smooth and efficient MM process by optimising the workflow. The concerns and constraints identified through data collection served as the guidelines for formulating the framework. A formulated framework recommends the use of Autodesk Revit, MSP, and MSA to optimise the workflow of the construction MM process. The proposed digital tools, as specified in the order, are expected to be more efficient for the stated purpose. However, the validation of the complete framework is not performed as part of this study. Only part of the proposed framework – MSP has been validated, and the results are as discussed below.

- **Ability to Map the Data Efficiently** – Quantities required for each activity and the location of utilization can be easily mapped.
- **Précised Budget & Material Requirement Identification** – Compared to the availed project data, there was an increase of 1% cost in the overall project budget when planned in MSP. That was due to the task mentioned in the schedule; however, the required material was missing from the Bill of Quantities (BOQ) listing.
- **Easy Cross verification**
- **Easy Documentation** – This reduces the load of handling fragmented documents.
- **Data-Driven Decision Making – Customizable reports keep you informed of the requirements.**
- **Visibility** - Multi-dimensional visibility to the data.

Despite the proven efficiency, to increase the rate of digital adoption, organisations must



# Workflow Optimization of Material Management Process by Digital Adoption in Indian Residential Projects

plan and conduct periodic training and development sessions for construction professionals to keep them informed about current research trends, enabling them to stay updated and benefit from collaborative efforts.

## FURTHER SCOPE OF RESEARCH

Results and discussion on the validation of a complete framework would be the ideal further step to support the study. Application in a project requires intervention from the design stage through to complete construction to identify the benefits, viability, and constraints of the proposed framework.

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