

# IMPACT OF BIM ON LABOUR PRODUCTIVITY

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**Abstract** - The main objective of this study is to study the factors affecting Labour productivity by Relative Importance Index method. Comparative study of labour productivity factors of conventional method and BIM. Study the barriers of implementation BIM. Benefits of BIM implementation for BIM-based quantity take off and scheduling. Labour productivity factors that affect the construction rate. Additional study is required to grant institutions to assess the impact of BIM on labour productivity. Measuring the impact is not reliable because of the sheer complexity

This study is represented as a result to overcome the decline and stagnation of labour productivity in construction business. Several strategies are developed on potential BIM to for the improvement of labour productivity through project coordination and proper management. Many of the factors affecting labour productivity have been studied and reported to study the impact of BIM on labour productivity. 20-50% of total construction cost comprises of labour cost. This can be reduced by improving labour productivity.

**Key Words:** Building information Modeling(BIM), Computer-aided design(CAD), Microsoft Project(MSP), IBIM (Information Building Information Modeling)

## 1.INTRODUCTION

Building Information Modeling (BIM) is process of generating functional and physical characteristics of places by a various tool, technology and contracts. BIM is a model-based process which grant perception for designing, planning, constructing and managing infrastructure and a building. Thus Building Information Modeling (BIM) is more than traditional CAD that provides various building components (for example, doors, windows, walls) along with system and building information in addition to simple dimensional relationship. BIM is 3D real time model that decreases the time and rework during construction of building. BIM started with common name for various activities in object oriented CAD that uphold the presentation of building element in terms of 3D geometry and non-geometric functional characteristic and relationship.

### 1.1 General

The BIM includes individuals from entire project (like architect, owner, engineer, facility management contractor etc.) who grant and relate with BIM team members who

produce more accurate modeling data. These models associate 2D and 3D object which represent building design including external parameters (such as geography location and local conditions) into virtual building. BIM model represents integrated source for all the information allied with building's design. Many implementation of BIM have been studied in literature survey. There is a substantial gap between early adopters and majority of usage in construction industry. There is generous financial risk for small/medium firms for implantation of BIM. Improved labour productivity has stimulating benefit in accepting and implementation of BIM.

Productivity may be defined in several ways. In construction firm, productivity means labour productivity that's unit of work produced or completed per man-hour. Inverse of labour productivity is man-hours per unit (unit rate) which is most certainly used. Certainly, this study is represented as a result to beat the decline and stagnation of labour productivity in construction industry. Several strategies are developed on potential BIM for the improvement of labour productivity through project coordination and proper management. Numerous factors affecting labour productivity have been studied and reported to study the impact of BIM on labour productivity. 20-50% of total construction cost comprises of labour cost. This can be reduced by improving labour productivity.

Additional study is required to grant institutions to assess the impact of BIM on labour productivity. Measuring the impact is not reliable because of the sheer complexity that require noticeable effort in gathering and analysing data in fields. In this study questionnaire survey is carried out to evaluate the factors affecting impact of Building Information Modeling on labour Productivity.

The main objective of this study is to study the factors affecting Labour productivity by Relative Importance Index method. Comparative study of labour productivity factors of conventional method and BIM. Study the barriers of implementation of BIM. Benefits of BIM implementation for BIM-based quantity take off and scheduling. Labour productivity factors that affect the construction rate.

### 1.2 Background of BIM

In the former, drawings and blueprints were used represent information about peculiar plan of building. 2D approach was very difficult for visualizing the dimensions. Next we updated it to Computer Aided Design (CAD)

which was more advantageous to see the model in virtual environment. Then came, three dimensional (3D) which was more realistic compared blueprints. Now, Building Information Modeling (BIM) is standard which is more than just a 3D model. Each project encompasses a level of uncertainty that must be managed without missing anything. Concept of BIM was first introduced in the year mid-1970 by Eastman with "Building Descriptive System (BDS)". After Eastman's paper evolution of BDS started in different places around world with different explanation. During 1970s and 1980s, USA based descriptions mentioned it as "Building Product Models" and European based descriptions mentioned it as "Product Information Models". Documented use of term "Building Modeling" is by Robert Aish in 1986. Van Nederveen and Tolman were first to use the term "Building Information Model" in their articles in 1992 and Jerry Laiserin was first to popularize the term "BIM".

### 1.3 Progression of BIM throughout the building's Lifecycle

Before BIM, CAD were used. Ingression of CAD software have simplified use of 3D model for architectural drawing. Recent years have witnessed the challenges to 3D model with fourth, fifth, sixth and seventh. Now even studies are going on eighth dimension that is related to safety of building throughout life cycle also during construction. 3D model is linked to scheduling of time that saves considerable time. 5D model is integration with 3D model for cost estimation. Entire building lifecycle sustainability refers 6D. 7D refers to all those models that encourage maintenance process. In recent study, multi-dimensional models are illustrated as BIM that is object oriented than a drafting / entity oriented. New digital information is working on nD modeling especially for dealing with historic heritage.

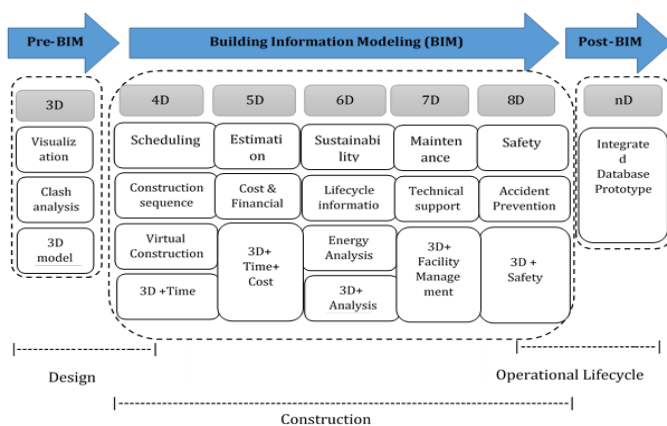


Fig- 1.1 Progression of BIM throughout the Building's Lifecycle

### 1.4 The "I" in BIM

BIM model as a whole refers to management of lifecycle and construction employing synergy and sharing data. Thus, true importance of BIM lies in information i.e. "I" in BIM. All the information summoned regarding building from generation to completion is not just summoned, it is actionable. This information is used for improvisation of accuracy and express the design target from workplace to construction site/field. It improves the transmission of information from stakeholder to stakeholder and reduces adjustment orders, field co-ordination issues and it also provides intuition for existing projects also for the purpose of renovation project later on.

### 1.5 Levels of BIM

There are various levels of BIM for numerous types of project. Each level presents a set of benchmark that shows a particular level of maturity. The purpose of Level of BIM is to gauge/benchmark how much data is being managed and shared throughout the project.

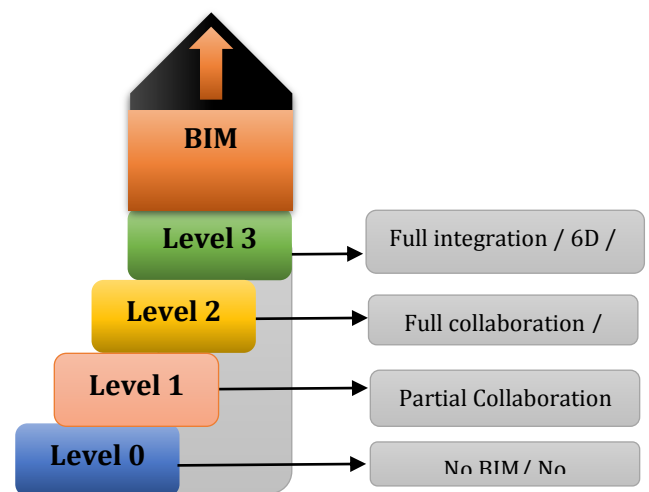


Fig-1.2 Levels of BIM

#### 1.5.1 Level 0

It indicates working without collaboration. If the project is being carried out with the help of 2D CAD, digital prints or drawings. Then it is said to be level 0. Most of the industries are still working above this level. There are still some experts who are uneasy about introducing new process or technology.

#### 1.5.2 Level 1

In this level, concept work is being done by 3D CAD. Drafting and other documentation is done by 2D. In this level, CAD are regulated to standards of BS 1192:2007 and electronic data sharing is done by common data environment mainly handled by contractor. Many of the

firms are at this level that doesn't involve much of the collaboration and each of the contractor publish and handle their own data.

### 1.5.3 Level 2

This level is a collaborative environment. This level is mandatory in UK on April 2016 for all publicly tendering projects. Here team members will be using 3D CAD models but not the same one. However, stakeholder's exchanges information in familiar file format. When the firm collaborate this shared information they save time, eliminate need of rework and cost overrun. Thus the CAD must be able to export an information to familiar file type such as IFC or COBIE.

### 1.5.4 Level 3

This level is further more collaborative. Rather than team member operating in their own 3D model. Level 3 is working in a specific shared model. The model is perhaps assessed and modified by everyone. This is termed as open BIM, here a layer of protection will be supplemented across clashes. UK has even promised mandatory use of Level 3 in coming years.

## 1.6 Importance of Labour Productivity in BIM

Labour productivity is unit of production produced or completed per man-hour. Inverse of labour productivity is man-hours per unit (unit rate) is commonly used. This study is represented as a result to overcome the decline and stagnation of labour productivity in construction business. Several strategies are developed on potential BIM for the improvement of labour productivity through project coordination and proper management. Many of the factors affecting labour productivity have been studied and reported to study the impact of BIM on labour productivity. 20-50% of total construction cost comprises of labour cost. This can be reduced by improving labour productivity. Effects of labour productivity vary from tasks to tasks. Even though some factors may have same affect but the rate of effect varies. Some of the bad impacts that can be improved by labour productivity are:

- Development of techniques and experience of individual.
- Proper management in construction business.
- Raising interest and agenda among labours.
- Minimize insufficiency of material.

## 2. METHODOLOGY

### 2.1 Case study

To demonstrate how Building Information Modeling (BIM) can be used. A case study of Basement + five-storey apartment project is taken. To achieve the goal 3D model

was prepared. Clash detection is carried out. BIM-based scheduling was prepared by making schedules and then linking it to Navisworks. Quantity take-off was also prepared.

By following methodology, 3D model was prepared by Autodesk Revit. Clash detection was done by exporting the Revit model to Navisworks in .NWC file format. Then scheduling is done by MS Project then linked to Naviswork model. Different colors were used to show the activity change.

### 2.2 BIM Process

Main difference between conventional CAD and BIM is that the BIM represents 3D model along with all the information. After the model is done all the details about the model such a schedules, quantities, 3D views, ceiling plan, floor plan, Renders, Sections, Elevations and perspective are automatically ready. It is convenient to switch or edit the components in BIM. Model even includes information and smart objects that have functional and physical characteristics. BIM includes all the necessary data that help in reducing time, cost overrun and delays throughout building life cycle. BIM model is prepared in the following ways:

#### 2.2.1 3D modeling

BIM presents maximum level accuracy model only if the data is inputted with certain high level accuracy into model. For this reason, information/ data is key factor in three-dimensional model. Material properties, family parameters, unit costs and component properties can be stated in the model. 3D model comprises of geometrical (dimension and shape), topological information and related additional information. This information cannot be included in conventional 2D CAD. A five-storey building project was assessed for this purpose. The 3D model was prepared by using Autodesk Revit. A B+ five storey building was assessed for the function of study. Using Revit architectural model was created. Information was stored with the project. After creation of wall, stairs, doors, windows and roofs sheets structural foundation was created.

#### 2.2.1.a Clash Detection

After creating 3D model, clash detection was conducted. For this, 3D Architectural model was exported to .NWC file format by Revit add-in. Then Water supply and Sewer connection .NWC are merged to Architectural model. In selection A, Architectural model was selected and in selection B Water supply and Sewer connection model was selected. After this process, clash detective tool was used for clash detection. All the clashes were detected depending upon the color coding. All the model (i.e. Architectural, Structural, Mechanical, Electrical and

Plumbing) can be appended to check clash detection which helps to save time and cost before actual construction. Clash detection is done on completed 3D model before the actual construction starts. With traditional 2D CAD drawings many problems will be occurred during construction which need to resolved and takes time for change in design. It helps in reduction in additional cost and time. Interference is checked through Revit interference check is done by Interference Check tool under coordinate panel.

**2.2.2 BIM-based 4D scheduling (4D Simulation)**

Scheduling is precisely relevant to time. 4D model comes from the completed 3D model that is related to project schedule. 4D simulation is process that controls and arranges construction task based on 4D model. Here 5 colors are used to indicate construction work status. Red indicates work under construction. Blue indicates completion of work on time. Yellow indicates work which are just finished. Orange indicates works which are not yet started. Pink indicates completion of work before scheduled time. Virtual building helps to identify the conflicts and errors before actual construction starts. Review sequence of work in construction 4D simulation is used. Navisworks is used for the visualization of model and change of color indicates activity change. Parameter was first created in shared parameter under manage panel and then it was added in Project parameters as TaskID. Then task ID were assigned to each of the elements and then the file was imported to Navisworks. The sets were attached to each of the task. Scheduling of activities was done by MS Project and it was imported to Navisworks. After importing Revit Model and Scheduling in timeliner. Sets will be created by searching them using tool “find object”. Each of sets will be attached to task by auto-attaching or manually. Then simulation will be carried out.



Fig- 3.1: Workflow of creating 4D model

**2.2.3 BIM-based cost estimation (5D)**

5D model is inclusion of cost into BIM model. Important thing is to do estimation to check feasibility. If the cost is over budget, then designs must be changed and revisions can be made. Using BIM, accurate calculations can be made. Estimation is done by Revit from view panel.

Table-3.1: Project phases

Project Phase	Details	Softwares used
3D Modeling	3D model is prepared using Revit.	Autodesk Revit
Clash Detection	To determine the conflicts before	Autodesk Revit, Autodesk

	construction stage and check the geometry of building.	Navisworks
BIM-Based Scheduling	Scheduling is prepared and linked to Navisworks for visualization of project according to schedule.	Autodesk Revit, Autodesk Navisworks, MS Project, Excel
BIM-Based Quantity take-off	Quantity take-off is prepared by Revit in view panel using Schedules tool.	Autodesk Revit, excel

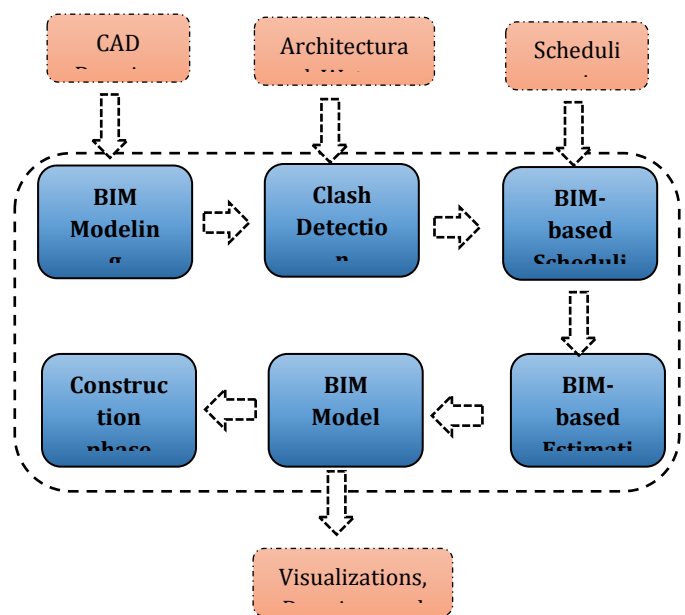


Fig- 3.2: Flowchart of BIM process

**2.2.4 Factors affecting Labour Productivity**

It is one of the major part of construction which directly affects the rate of construction. With the increase in Labour Productivity, increases the efficiency of construction work. In this, questionnaire was prepared and distributed among respondents. Respondents were asked to rate within 1 to 4 to resolve level of effect. RII was used for analysis.

The RII is regression-based index which is the mean factor that gives weight by insight of respondents. RII is method which helps to determine what actually people need by asking them some questions. It helps in determining various factors affecting Labour Productivity. By using RII analysis important factors are identified depending upon the participant’s reply.

RII equation is given below,

$$RII = \sum W / (A*N)$$

Where,

A is the highest weight i.e. 4

N is total no. of responses collected.

W is rate given by each respondent ranging from 1 to 4.

W ranges are as given below

4= Highly affects

3= Some-what affect

2= Does not affect

1= Not applicable

### 3. RESULTS AND DISCUSSIONS

Project selected for the implementation of BIM is five-storey building (i.e.22,000 sq. ft. area). It is located in Hubli and total budget of the project is approximately Nine crores. The project was divided into 4 Blocks as Aster, Blueberry, Cherry blossom and Daffodils as shown in Fig. 3.1



Fig- 3.1: Completed 3D model

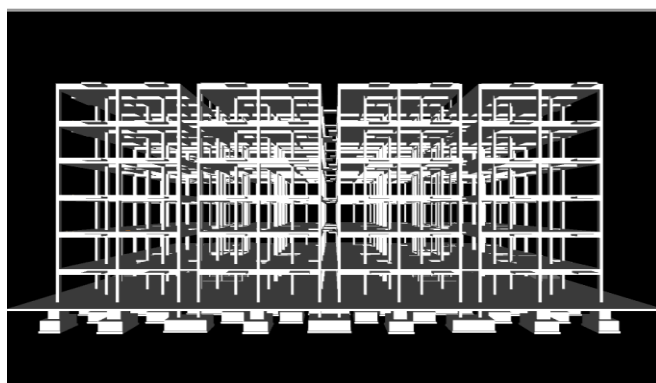


Fig- 3.2 Completed Structural model in Navisworks

#### 3.1.1 Clash Detection

After creation of Basic 3D model in Revit. Different Designs are carried out parallelly on the same basic model. Then clash detection is achieved on model by appending then in Navisworks Manage. Fig. 3.3 shows the Clash detection achieved on the model.

Clash detection was achieved by selecting the completed 3D model in part A selection and then selecting plumbing and sewer connection in part B. Then by running hard

clash detection. There were total 42 hard clashes detected which were reviewed and then resolved.

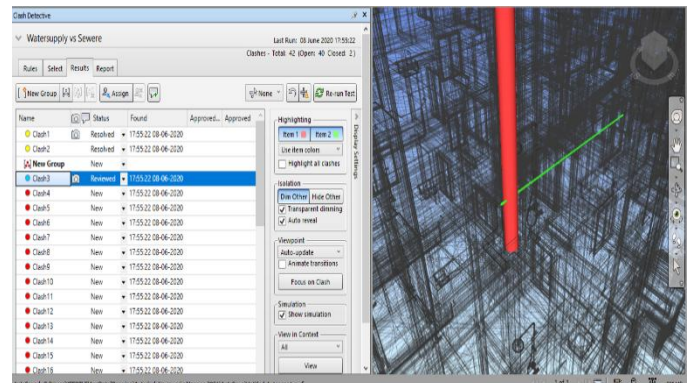


Fig- 3.3: Clash detection carried out on the model

#### 3.1.2 4D Simulation

After Completing the model, simulation was carried out to review the sequence of work carried out. Virtual 4D simulation helps to identify the conflicts and errors before actual construction starts. Fig. 4.4 and 4.5 shows creation of parameters and adding them to project parameters. Fig. 4.6 shows the 4D scheduling of project. MSP was imported to Navisworks and then by attaching the sets to each element. Each of the parameters were attached and then simulation is done by using simulate in Timeliner tool. Attaching the sets can be done by auto attaching or by manually. Fig 3.7 shows the simulation of project.

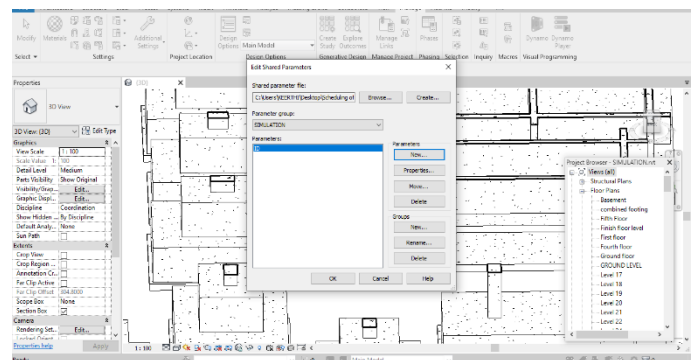


Fig- 3.4: Creating shared parameters

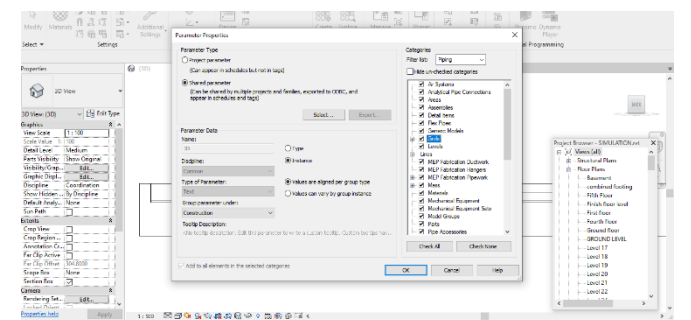


Fig- 3.5: Adding shared parameters to the project parameter

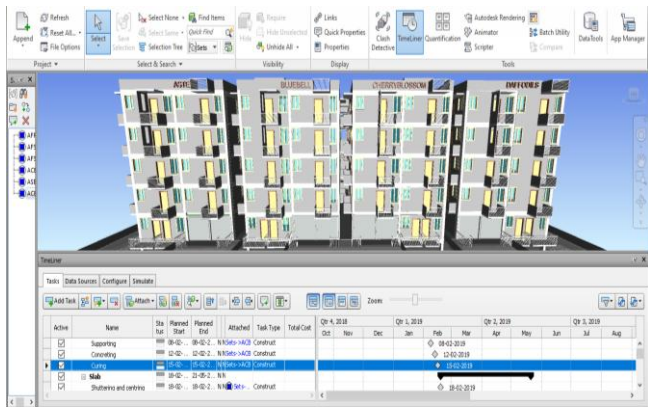


Fig- 3.6: BIM-based 4D Scheduling

### 3.2 Questionnaire Survey analysis

Some of the factors affecting Labour Productivity are listed in the table 4.1 and rating given by the respondents are calculated by RII method. All the sub factors are divided into major factors that are Personal factors, Organization, Environmental conditions, Proficiency of labours, Incentive schemes, conditions of site, Safety of Labours, Project and Planning. According to rating given by respondents ranking is given to each of the project to know factors which affects more on Labour productivity and to resolve them to get higher productivity. Respondents Name, Profession, Softwares used, Barriers and Benefits of using BIM were noted down.

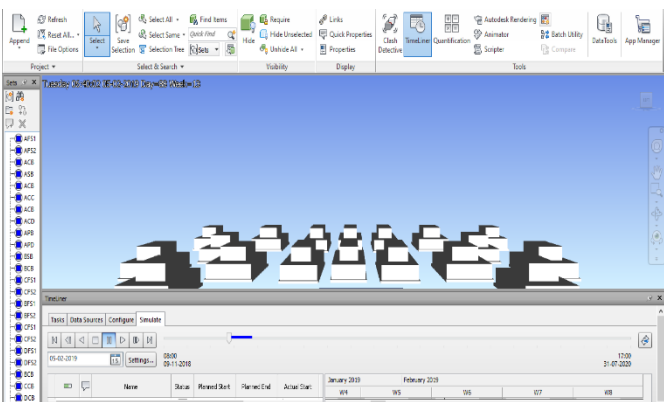


Fig- 3.7: BIM-based 4D Simulation

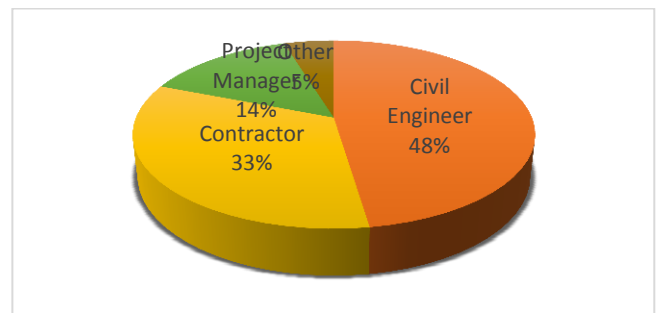


Fig- 3.9: Percentage of Respondents on the basis of their occupation

### 3.1.3 5D Quantity take-off based on 3D model

BIM-based quantity take-off was carried out on 3D model. Material take off, windows and doors take-off was carried out to generate complete BIM-based estimation then they were exported to Excel. Fig. 4.8 shows the BIM based quantity take-off.

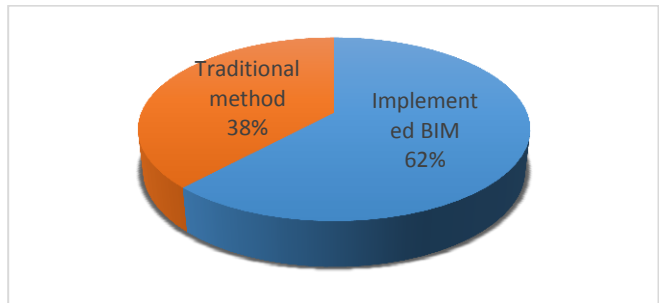


Fig- 3.10: Percentage Implementation of BIM

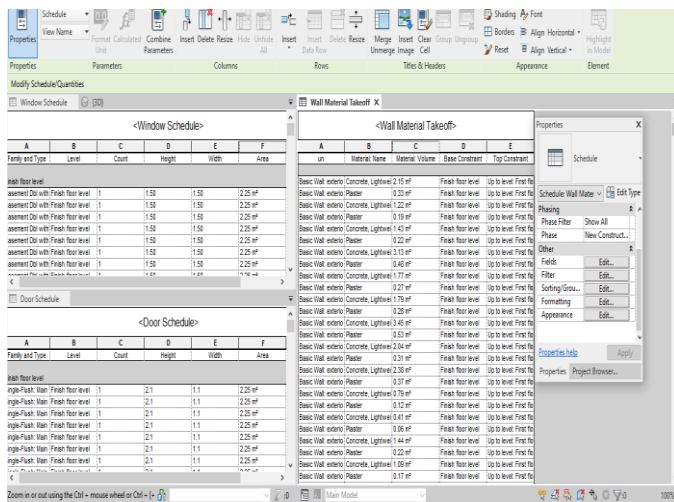


Fig- 3.8: BIM-based Quantity take-off

Result shows that out of 21 respondents 13 have implemented BIM (i.e. 62%) and remaining 8 (i.e. 38%) still use convention method for the designing. Among all the softwares available CAD and Revit are most commonly used for designing.

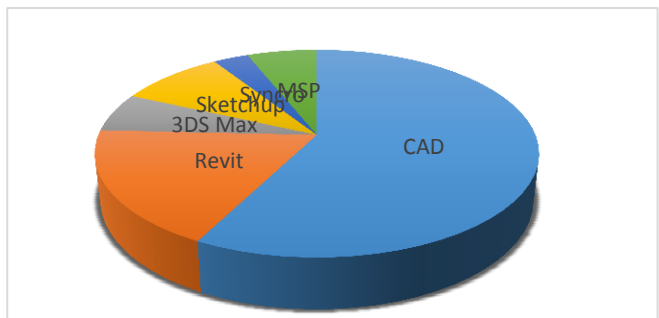


Fig-3.11: Softwares used by the respondents

Depending upon the rating given by the respondents, ranking is given to each of the factor to know which of these factors affect construction. Proper planning, Labour supervision, scheduling of work, Project manager’s leadership, Payment for extra work, Skilled labour, Time management, Unforeseen disaster, Experience of Labour and Sub-contractor management are the major factors affecting construction which need to be taken care.

**Table- 3.1** Results for factors affecting Labour Productivity

	Ranking	RII
<b>Personal Factors</b>		
Age of labour	22	0.3186
Experience of labour	7	0.3858
Multiple shifts	33	0.3369
Motivation to labour	33	0.3369
No. of labours on site	41	0.2981
Facilities provided to labours	22	0.3586
Relation between workers	39	0.3152
<b>Organization</b>		
Firm reputation	45	0.2608
Training of labours	22	0.3586
Communication between site engineer and labour	21	0.3641
Project Manager’s leadership	3	0.3967
Governmental regulations (building codes, etc.)	41	0.2989
<b>Environmental conditions</b>		
Climatic conditions	26	0.3532
Temperature on site	31	0.3423
<b>Proficiency of Labour</b>		
Skilled Labour	7	0.3858
Labour Supervision	2	0.4130
<b>Incentive schemes</b>		
Wages	16	0.3696
Expectations out of labours(outcome)	33	0.3369
Unscheduled extra work	27	0.3478
Payment for extra work	5	0.3913
<b>Conditions of site</b>		
Availability of materials and tools	12	0.3804
Procurement type and delivery mode	37	0.3260
Sequence of work	16	0.3695
Project size and complexity	39	0.3152
Material storage location	31	0.3423
Structural design complexity	16	0.3695
<b>Safety of Labour</b>		
Safety conditions on site	16	0.3695
Working conditions (lighting, noise etc.)	22	0.3586
Stacking of trades	27	0.3478
Unforeseen disaster/ natural disasters	7	0.3858
<b>Project</b>		
Competencies of the project team	44	0.2826
Construction method	5	0.3913
Rework	27	0.3478

Site layout	46	0.2336
Travel distance to worksite	33	0.3369
<b>Planning</b>		
Availability of skilled labours	12	0.3804
Time management (efficient use of time)	7	0.3858
Scope or design changes	14	0.375
Uniqueness	14	0.375
Client interface	38	0.3206
Proper Planning	1	0.4293
Sub-Contractor management	7	0.3858
Scheduling of work	3	0.3967
Flow and coordination of work	16	0.3695
Cost predictability	41	0.2989
Cost management	27	0.3478

Comparative analysis was carried between BIM and traditional methods to know the affecting Labour productivity. Table 4.1 shows the results obtained from questionnaire survey questionnaire survey. Factors affecting are almost same for both methods. Factors affecting in BIM methods are proper planning, Labour supervision, skilled labour, construction method, payment for extra work, Construction method and scheduling of work. Factors affecting Labour productivity in traditional method are Project Manager's leadership, proper planning, Labour supervision, sub-Contractor management and scheduling of work. Along with the ratings, respondents were even asked to mention the benefits and barriers of using BIM.

**Table- 4.2** Comparative analysis of BIM and Conventional method

	Implemented BIM		Conventional method	
	Ranking	RII	Ranking	RII
<b>Personal Factors</b>				
Age of labour	23	0.2228	20	0.1358
Experience of labour	4	0.2445	13	0.1413
Multiple shifts	23	0.2228	39	0.1141
Motivation to labour	23	0.2228	39	0.1141
No. of labours on site	40	0.1848	39	0.1141
Facilities provided to labours	23	0.2228	20	0.1359
Relation between workers	38	0.2011	39	0.1141
<b>Organization</b>				
Firm reputation	44	0.1522	45	0.1087
Training of labours	30	0.2173	13	0.1413
Communication between site engineer and labour	15	0.2336	26	0.1304

Project Manager's leadership	8	0.2391	1	0.1576
Governmental regulations (building codes, etc.)	43	0.1630	20	0.1359
<b>Environmental conditions</b>				
Climatic conditions	8	0.2391	39	0.1141
Temperature on site	30	0.2174	32	0.1250
<b>Proficiency of Labour</b>				
Skilled Labour	3	0.25	20	0.1358
Labour Supervision	2	0.2554	1	0.1576
<b>Incentive schemes</b>				
Wages	8	0.2391	26	0.1304
Expectations out of labours(outcome)	35	0.2065	26	0.1304
Unscheduled extra work	21	0.2228	13	0.1413
Payment for extra work	4	0.2446	6	0.1467
<b>Conditions of site</b>				
Availability of materials and tools	8	0.2391	13	0.1413
Procurement type and delivery mode	35	0.2065	38	0.1196
Sequence of work	21	0.2283	13	0.1413
Project size and complexity	42	0.1739	13	0.1413
Material storage location	30	0.2174	32	0.1250
Structural design complexity	8	0.2391	26	0.1304
<b>Safety of Labour</b>				
Safety conditions on site	23	0.2228	6	0.1467
Working conditions (lighting, noise etc.)	15	0.2337	32	0.1250
Stacking of trades	33	0.2120	20	0.1359

Unforeseen disaster/ natural disasters	8	0.2391	6	0.1467
<b>Project</b>				
Competencies of the project team	44	0.1522	26	0.1304
Construction method	4	0.2446	6	0.1467
Rework	35	0.2065	13	0.1413
Site layout	46	0.1413	46	0.0924
Travel distance to worksite	33	0.2120	32	0.1250
<b>Planning</b>				
Availability of skilled labours	15	0.2337	6	0.1467
Time management (efficient use of time)	8	0.2391	6	0.1467
Scope or design changes	15	0.2337	13	0.1413
Uniqueness	21	0.2283	6	0.1467
Client interface	39	0.1902	26	0.1304
Proper Planning	1	0.2717	1	0.1576
Sub-Contractor management	15	0.2337	4	0.1522
Scheduling of work	4	0.2446	4	0.1522
Flow and coordination of work	15	0.2337	20	0.1359
Cost predictability	40	0.1848	39	0.1141
Cost management	23	0.2228	32	0.1250

#### 4. CONCLUSIONS

This study represents a BIM-based model for construction projects for investing how BIM impacts Labour productivity. For this purpose, a B+5 storey building was chosen as a case study. The case study determines how BIM grant effective sharing of a 3D model that has all the data necessary for all the process. After completion of all the required data in a 3D model, required elevations, sections, Renders, schedules and quantity take-off can be generated automatically. Additionally, ability to detect clashes, defects or errors of project in early design stages before actual construction starts that helps to avoid unnecessary costs.



Questionnaire survey was sent to 21 respondents among which 13 have implemented BIM (i.e. 62%) and remaining 8 (i.e. 38%) still use convention method for the designing. Among all the softwares available CAD and Revit are most commonly used for designing. Depending upon the rating given by the respondents, ranking is given to each of the factor to know which of these factors affect construction. Proper planning, Labour supervision, scheduling of work, Project manager's leadership, Payment for extra work, Skilled labour, Time management, Unforeseen disaster, Experience of Labour and Sub-contractor management are the major factors affecting construction which need to be taken care.

Benefits of BIM begin at early stage and cover entire lifecycle. Some other benefits given by respondents are Better project coordination and collaboration with stakeholders, efficient workflows, 3D visualizations, and resulting improved project, Early detection of construction errors which eventually decreases cost and time overrun, work can be completed on time by proper management and efficient use of time and labour. Barriers given by respondents for not implementing BIM are lack of knowledge about BIM, still not used in our country due to cost implementation, lack of Knowledge among the people, less availability of resources and validation of data is also a challenge, no proper training available and cost of software and no proper training.

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