International Journal of Advanced Research and Review

www.ijarr.in

BIM BASED PERFORMANCE IMPROVEMENT IN CONSTRUCTION MANAGEMENT BY PREFABRICATION

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ABSTRACT

Big changes don't come easy for something as large as the construction industry, and when they do happen, they don't happen all at once industry wide. Change occurs project by project, and company by company. BIM is currently making it more possible or feasible to do, but the real driver will be owners seeing examples from elsewhere in the world and starting to demand it for their projects. While projects of almost any size can benefit from prefabrication, it has perhaps the greatest impact in larger, more complex projects. These projects are often managed by a larger general contractor or construction manager, who will prefabricate mechanical, electrical, and plumbing equipment, which can be delivered to the jobsite and installed by smaller trade subcontractors exactly when needed. Building Information Modeling "BIM" is becoming a better known established collaboration process in the construction industry. Owners are increasingly requiring BIM services from construction managers, architects and engineering firms. Many construction firms are now investing in "BIM" technologies during bidding, preconstruction, construction and post construction. The goal of this research is to understand the uses and benefits of BIM for construction managers and examine the impacts of prefabrication in BIM for a specific residential case study. Almost for results we must show the ranges of saving in different stages of construction by prefabricated elements and also using BIM tools.

Keywords: Prefabrication- BIM- construction management

INTRODUCTION

In this section we discuss about the role and use of Building Information Modeling from the Construction Management point of view. First we start with history of construction industry after that BIM is reviewed and defined. Then, the uses of BIM which include wide aspects of construction regarding to prefabrication and its benefits and barriers in lifecycle of a project were discussed in detail.

1-1- HISTORY OF CONSTRUCTION INDUSTRY:

The construction industry has experienced a gradual decrease in its labor productivity since the early 1960s. In the meantime, the non-farm industries such as the manufacturing industry have increased their labor productivity. The reduction of labor productivity in the construction industry requires more labor hours per contract dollar amount. This indicates that construction industry is lacking the development for labor saving ideas. Figure 1 depicts the gap between the non-farm and construction industry labor productivity [1].

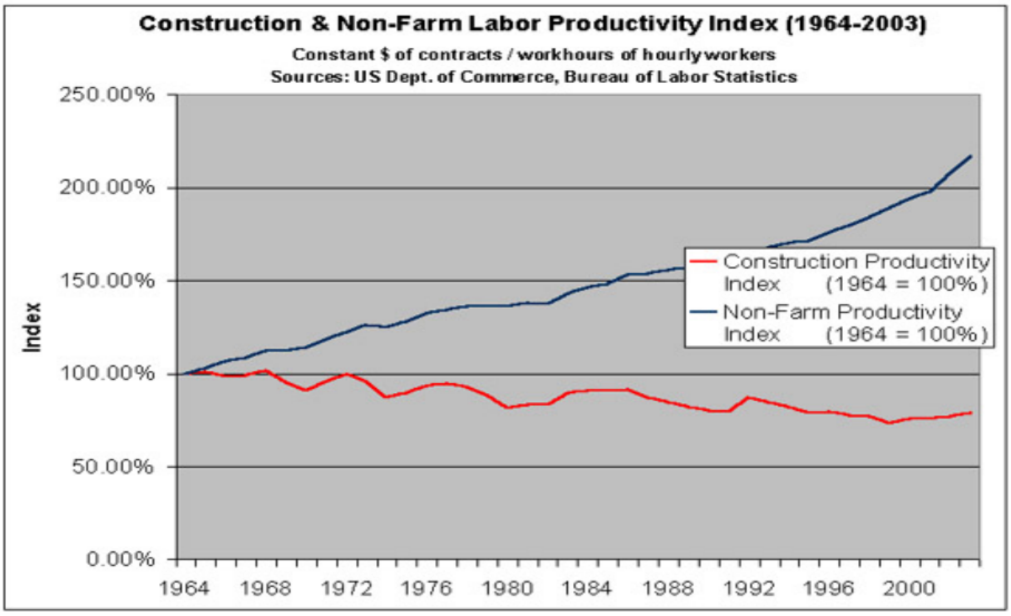


Figure 1: Construction and Non-Farm Labor Productivity Index [1]

The main causes of the lack of labor productivity in the construction industry are related to its fragmented nature due to traditional project delivery approach, traditional use of 2D Computer Aided Drafting (CAD) technology and the size of construction firms [1].

One of the first steps towards the use of 3D technology in the construction industry was initiated as a 3D solid modeling in late 1970s. During this time, manufacturing industry carried out product design, analysis, and simulation of 3D products. 3D modeling in the construction industry was hindered "by the cost of 3 computing power and later by the successful widespread adoption of CAD" [2].

Construction industry has established the basis of object-oriented building product modeling in 1990s. Initially, certain market sectors such as structural steel utilized the parametric 3D modeling. Recently, various BIM tools became readily available throughout the construction industry. This is a reward of construction industry's dedication to Building Information Modeling for the last 20 years [2]. Construction industry has come to a point to realize the true benefits of technological advancement. The labor efficiency gap can be closed via the Building Information Modeling concept. Therefore, it is the intention of this project to study BIM and its tools to determine benefits and setbacks it poses to construction managers at risk.

1-2- WHAT IS BIM?

The Building Information Model is primarily a three dimensional digital representation of a building and its intrinsic characteristics. It is made of intelligent building components which includes data attributes and parametric rules for each object. For instance, a door of certain material and dimension is parametrically related and hosted by a wall. Furthermore, BIM provides consistent and coordinated views and representations of the digital model including reliable data for each view. This saves a lot of designer's time since each view is coordinated through the built-in intelligence of the model. According to the National BIM Standard, Building Information Model is "a digital representation of physical and functional characteristics of a facility and a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition" [3].

Building Information Modeling (BIM) is the process and practice of virtual design and construction throughout its lifecycle. It is a platform to share knowledge and communicate between project participants. In other words, Building Information Modeling is the process of developing the Building Information Model.

1-3- USE OF BIM IN CONSTRUCTION MANAGEMENT

There are many uses of Building Information Modeling for each project participant. Figure 2 depicts these uses for the planning (conceptual phase), design development, construction and operation (post construction) phases:

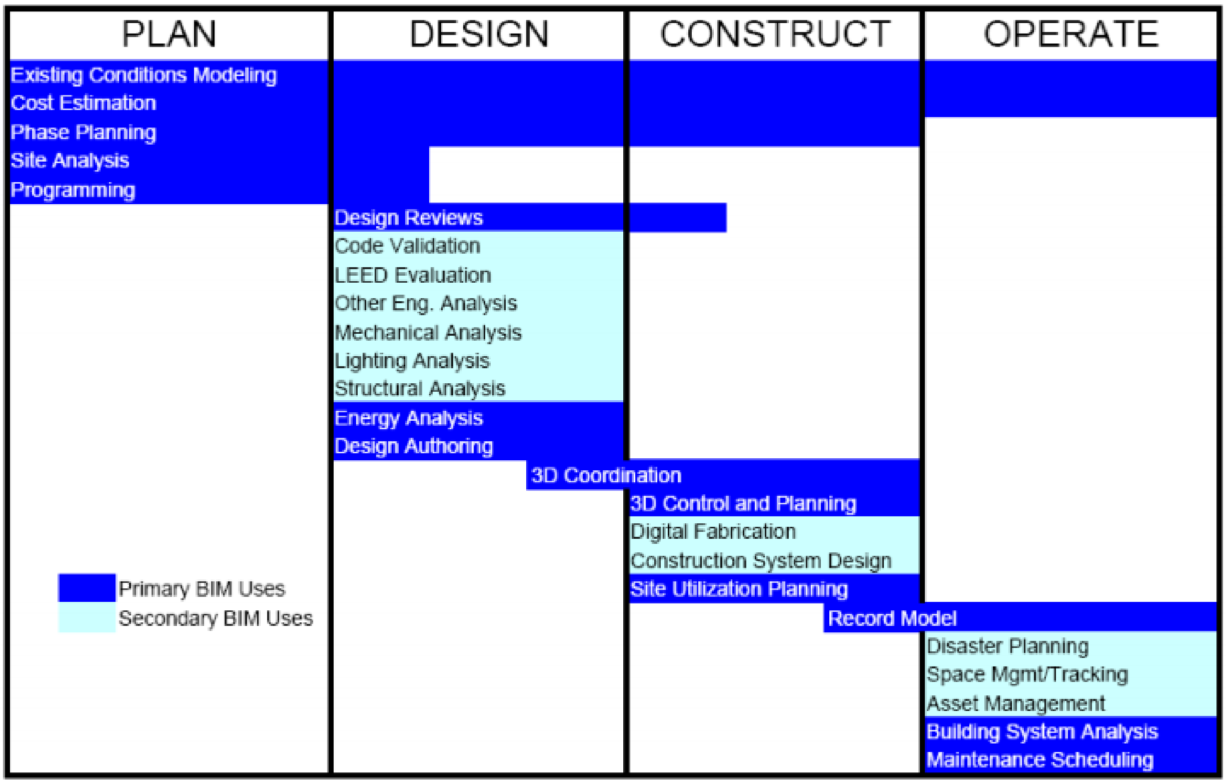


Figure 2: BIM Uses throughout a Building Lifecycle [4]

During the conceptual phase we involve with:

- Planning of design team
- Barriers
- Technology developers
- Stakeholders

During the conceptual phase we involve with:

- Socio economic profile
- Stakeholders
- Users
- Technical team

And During the construction we involve with:

- Measurement
- Verification
- final acceptance and reports

During the design phase, the use of BIM can maximize its impact on a project since the ability to influence cost is the highest. The team can creatively come up with ideas and provide solutions to issues before problems become high cost impacts to the project. This can be realized through the cooperation and coordination of the entire project staff. Therefore, it is extremely important to have a good collaboration. The use of BIM especially enhances the collaborative efforts of the team. The architect and engineer can test their design ideas including energy analysis. The construction manager can provide constructability, sequencing, value and engineering reports. They can also start 3D coordination between subcontractors and vendors during early stages of design. The owner can visually notice if the design is what he is looking for. Overall, the BIM promotes the collaboration of all of the projection participants. There are beneficial uses of BIM during the construction phase. However, the ability to impact the cost in a project reduces as depicts in figure 3 as the construction progresses.

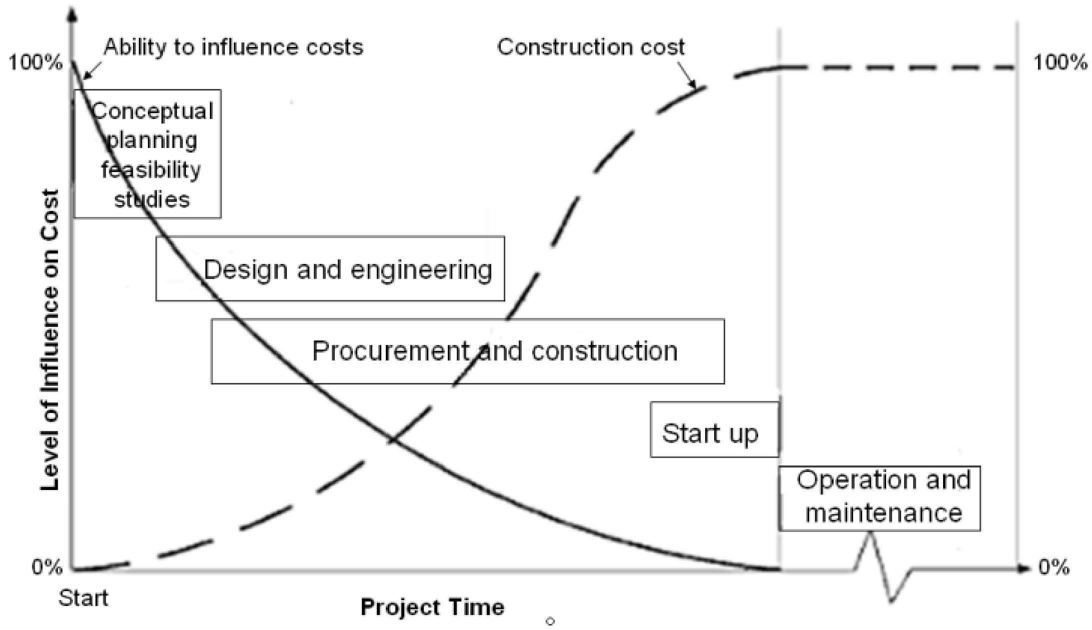


Figure 3: Project Life Cycle - ability to influence cost [2]

1-4- PREFABRICATION

Prefabrication reduces field labor cost and time and increases accuracy in a good quality construction. There are more tools and options readily available in a controlled environment of the jobsite to perform work more precisely, and less costly in a shorter period of time. Prefabrication requires design and field accuracy. Building information models can provide this level accuracy by including the specifications, sequence, finishes, and the 3D visual for each component. However, the construction team must make sure that the BIM is interoperable with the software used by fabricators. This way the contractors can use the BIM and generate details for the product in their fabrication software. Once the details are approved, the products can be fabricated using Computer Numerical Control (CNC) machines. Furthermore, the construction managers must administer the procurement schedule of the products. Overall, the prefabricated products must be delivered to the jobsite on time. Difficult steel connections generated in Building Information Model can be welded offsite. The welding of these small complex elements in advance of steel erection can save time and money. Furthermore, BIM helps to timely modify designs to eliminate or reduce use of beam penetrations that may result from MEP conflicts. A few beam penetrations may become inevitable for complex project. A good coordination of these penetrations with BIM technology advocates determining the beam penetration locations and prefabricate offsite. Prefabricated beam penetrations would save tremendous time, money and effort in comparison to onsite beam penetrations. Moreover, roof penetrations for concrete rooftops should be sleeved prior to concrete pour at the roof level. Supplemental steel for each penetration may be required. These penetrations can be coordinated with BIM when the specialty contractors are on board [5]. Curtain wall systems whether panelized or stick system, can be used with BIM to prefabricate parts and components. Panelized curtain wall systems may be considered for the schedule purposes. Stick systems require the use of assembly of each one of components onsite whereas the panelized systems already come prefabricated with all the components which include insulation, glazing, stone, framing, etc. Walls, rooms, and houses can be virtually designed and constructed with Building Information Model. These walls, rooms and houses can be prefabricated with roughed mechanical, electrical, plumbing (MEP) components. Final MEP connections can be made once the prefabricated components are assembled onsite. In healthcare and biotechnology projects, various equipment such as Biosafety Cabinets (BSCs), fume hoods, autoclaves, cage washes, and MRIs, etc. may be required. This equipment may require some type of coordination with MEP contractors. For instance, fume hoods may come with prefabricated piping for vacuum, gas, or nitrogen lines at laboratories. BIM can be used to determine the exact location of the fume hood and more importantly, the drop in location to the prefabricated piping at the fume hood. This enables the in-wall roughing and plumbing drops of the piping work before the fume hoods come to the site. Moreover, the electrician can pull cables to junction box to later tie into the circuits for lights, outlets, and fan. Lastly, the ductwork contractor can use the information from the BIM to drop its branch duct so the fume hood can later be tied in. Overall, Building Information Modeling can help achieve the implementation of the MEP roughing work by promoting collaboration of information exchange between the subcontractors. BIM can help to coordinate between casework installers and MEP contractors. For example, island benches (cores) are prefabricated with electric outlets, and gas turrets. BIM can be used to determine the roughing locations. Then, the electrical circuits of the island benches can be roughed to a junction box. The plumbing pipes can be fed to the horizontal branches above the ceiling. Overall, the roughing can be completed successfully with the use of Building Information Modeling process. Pipe manufacturer could use BIM to gather coordinated piping locations, lengths and sizes for its fabrication software as long as the interoperability is possible. This allows in-wall drops including hot, cold, drain/vent, vacuum, etc. to be prefabricated. The drops typically stick out a foot from the wall to provide connection to the horizontal branches above the ceiling. Furthermore, if pipes need to be weld, they must come at manageable sections. Pipes typically come to jobsite 5 to 10 feet sections. Welding small sections of black iron pipe with four inches or bigger diameter would be feasible to weld offsite whereas two 10 foot sections welded offsite would not be manageable. Also, offsets and joints would prefer to be prefabricated. Overall, it is ideal to prefabricate all the small pieces in a controlled environment with readily available equipment which would yield more efficient, higher quality, and less costly products [5]. BIM can be used to enhance the information exchange of the products between participations. Furthermore, it is used to virtually coordinate the location and routing of the products. Based on this information, the products can be detailed using the fabrication software. Once the material is prefabricated and arrives on site, the foreman of the specialty trade coordinates with the general superintendent to ensure that he is making the virtual design and construction a reality.

2- LITERATURE REVIEW

In Chapter 1, the terms BIM, and related terminologies were defined. The use of BIM which include prefabrication was further examined and now we will mention examples of prefabricating and construction management.

- The Summit at Queens College Student Residence Hall

The project mainly employed prefabrication in two ways. The first was the use of prefabricated concrete floor planks, a relatively common practice. However, they also decided to create lightweight, load-bearing prefabricated exterior walls, a new approach that the team developed just for this project. The system consists of wall sections that typically measure 30 feet. Each involves a metal stud structure with nearly all of the wall components factory installed, including glazing, exterior skin, insulation, vapor barriers— every component except the electrical wiring and interior sheetrock. For the system to work effectively for a multistory building, it had to be lightweight, as Eric Goshow, a partner at Goshow Architects, explains. “We wanted to make it lightweight so that it could be easily transported, and would reduce the weight in the bottom of the building and the size of the footing.” That goal led to the use of high-strength, lightweight metal studs in the panels. In addition, the brick used as the primary exterior finish for the building was one inch split tile as opposed to typical four inch face brick, which also significantly reduced the weight of the panels [6].

The wall panels used to create the Summit project include a wide range of exterior materials, including brick and metal panels [6].

- Texas Health Harris Methodist Alliance Hospital

Do the BIM model for these horizontal systems and [the prefabrication firms] have developed software that converts the BIM model into a bill of materials on a prefab rack by prefab rack basis.” These racks combine the work of multiple trades, including duct work, medical gas mains, hot water supply and return for comfort heating, domestic water piping, electrical conduits, communication system pathways and low-voltage systems. Typically, in the U.K. these racks are assembled in factory and shipped to the site [6].

The hospital will feature multi-trade prefabricated racks in the corridors, an approach that is still new in the U.S.[6].

The multitrade racks were the most innovative use of prefabrication, but not the only example of this approach. The patient rooms will also have prefabricated bathroom modules and headwalls. Wilson states that “those two components are a win on every facility we will ever do” because of the efficiency and quality of the construction.

We can mention the ability to conduct sound attenuation studies of the headwalls at the factory as a factor that contributes directly to patient satisfaction. Finally, there will likely be few deviations from the schedule [6].

- Fort Sam Houston Medical Education and Training Complex Barracks

The basic project scope called for facilities to house a total of 6,000 soldiers, as well as a mix of administrative offices and classrooms. In order to meet the tight schedule of 42 months and budget constraints, general contractor Hensel Phelps of Greely, Colorado, and subcontractor the Warrior Group of DeSoto, Texas, devised a plan that heavily leverages permanent modular construction. The team worked with designer Carter Burgess (now part of Pasadena, California-based Jacobs) to assist in reimagining the design. The new plan calls for five four-story buildings, roughly 320,000 square feet each, to be built using a hybrid of site-built construction and permanent modular components. All of the barracks use modular construction, representing nearly 220,000 square feet of space per building.
Each building has a void form foundation sitting on piers that are driven between 65 feet and 70 feet deep. At the center of each facility’s footprint, site-built steel structures are used for a mix of classrooms, storage rooms, offices, elevators and mechanical rooms. Once that portion is completed, the modules are added, extending out as wings in the building. These wings turn in a series of 90-degree angles to form two courtyards. At each of the corners created by those 90-degree angles, site-built construction is again used to create classrooms, utility rooms and stairwells. Standard barrack modules include two living quarters per module, separated by a central corridor. Each weighs 35,000 pounds and is 60 feet long by 13.6 feet wide. Some modules are installed with one living quarter. The modules are “more than 85%complete when they arrive onsite,” says Ed Zdon, senior project manager with the Warrior Group. The rooms in each module include the shell, sheet rock, doors, light fixtures, Corian vanities, ceramic bathroom tiles, all utilities, and even the poles and shelves in the closets.

The modules are constructed at a facility in Belton, Texas, an approximately 2.5-hour drive north of Fort Sam. The manufacturer is able to construct and store hundreds of modules at no extra cost before they need to be shipped to the job site, according to Zdon. Although shipping of the modules can be costly, Zdon notes that they can be built at the factory rain or shine, unlike site-built construction, which is subject to weather delays [6].

At the center of each facility's footprint, site-built construction. Once the site-built portion is completed, the modular components are added, extending out as residential wings in the building. At each of the corners, site-built construction is used to create mechanical rooms and stairwells [6].

Modules are picked from a carrier bed by a crawler crane and stacked on top of each other with no additional structure. Crews install eight to 12 per day [6].

3- CASE STUDY

1 story family house in Soma, Manisa:

In this case study we want to realize the prefabrication systems in term of construction management of BIM. For this aim as a classification of construction management in chapter 1, we explain prefabrication process in each step.

Advantages and issues

Advantages

The advantages of using prefabrication in housing are that:

- prefabricated components speed up construction time, resulting in lower labor costs;
- prefabrication allows for year-round construction;
- Work is not affected by weather delays (related to excessive cold, heat, rain, snow, etc.);
- the mechanization used in prefabricated construction ensures precise conformity to building code standards and greater quality assurance;
- there are less wasted materials than in site-built construction;

- there is less theft of material/equipment (and less property damage due to vandalism);
- materials are protected from exposure to the elements during construction;
- worker safety and comfort level are higher than in site-built construction;
- computerization of the production process permits a high degree of customization, at an affordable cost;
- quality control and factory sealing and design can ensure high energy efficiency; and
- cost savings through prefabrication can reduce the income required to qualify for a high ratio mortgage by up to one third compared to a conventionally built home of the same size.
- Environmentally friendly way of building with optimum use of materials, recycling of waste products, less noise and dust, etc.

Issues

The issues related to using prefabrication in housing are that:

- many municipalities zone against manufactured housing because of earlier perceptions created by trailer parks;
- concerns have been raised by local and regional governments with regard to whether the taxation paid by manufactured homes is sufficient to offset public costs such as schools;
- the requirement to transport manufactured homes or modules to their intended site can mean that prefabrication potential may be limited for infill projects in inner city areas; and
- Increased production volume is required to ensure affordability through prefabrication.

Buildings of the demonstration district are owned by SOMA Electricity Generation & Trading Joint Stock Company and being used for its personnel. The “Soma Power Plant Lodging Buildings” site has nearly 160,600 m^2 land area that include 82 blocks with a total of 346 apartments, 2 guest houses and 1 convention center.

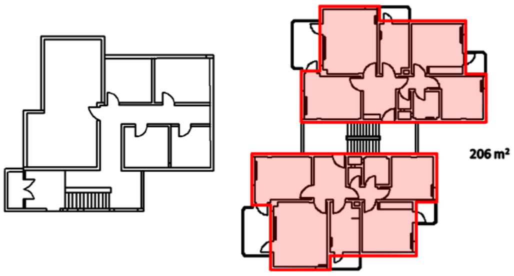
In total, 64,971 m^2 gross area in which, 41,158 m^2 corresponds to the conditioned area. The building blocks are categorized and identified according to these building typologies.

- **Residential building blocks** have a total 59,297 m^2 gross area and 36,257m^2 conditioned area as they are,
  - 3 story; 33 building blocks, (32,535 m^2 gross area – 20,374 m^2 conditioned area)
  - 2 story; 32 building blocks, (22,506 m^2 gross area – 13,171 m^2 conditioned area)
  - 1 story; 6 building blocks, (2,524 m2 gross area – 1,235 m2 conditioned area)
  - Duplex; 8 building blocks, (1,733 m^2 gross area – 1,477 m^2 conditioned area)
- **Guest houses** have two building blocks and total 3,028 m^2 gross area and 2,470 m^2 conditioned area**.**
- **Convention centre** has a total 2,646 m^2 gross area and 2,431 m^2 conditioned area.

Case study

1 story residential building:

A typical floor plan of residential building blocks and conditioned areas are shown on the figure below:



Here we explain prefabrication method in each stage of management for this one story residential building:

- Conceptual phase:
  1. Planning of the design team:

First of all we must specify which parts of building will be made of prefabricated elements. In this stage we choose prefabricated elements as windows, doors, walls, roof panels, ceiling structures, heating and cooling methods and even maybe furniture types, after all it's the time to choose the companies and make contacts with them.

  2. Barriers:

We most to pay attention most of the prefabricate elements have positive and negative aspects. We discuss about some benefits in chapter 1 but here are some barriers about them:

- Maybe after years the prefabricated element not be available to change or repair
- Maybe if we use same elements in more than one block for example façade prefabricated panels it will be make troubles for psychological state of residents…

3. Technology developers:
    - Selected prefabricated elements must be adoptable with technology expansion.
4. Stakeholders:
    - Managers must able to ensure stakeholders about the time and cost reductions of using prefabricated elements.
    - They must also explain the barriers and how to deal with them

- Design development:
    1. Socio economic profile:
        - Managers must realize the financial and social conditions of site to make proper choices about existent details and apply the best elements in project
    2. Stakeholders:
        - In this stage manager must make right communication between stakeholders to apply selected prefabricated elements.
    3. Users:
        - In 1story residential house we have a variety of users, the kids, Adolescents, parents and also elderly people. They have different comfort conditions and different demands. For example when we use a prefabricated door we must attention to all this parameters.

- Construction documentation:
    1. Measurement:
        - In this stage manager must control the dimension and scales of elements to be proper for a residential building and apply them.
    2. Verification:
        - After all this controls manager must verify the data to beginning the construction
    3. Final acceptance and reports:
        - After final acceptance they must report and document the processes.

4- CONCLUSION

Among the greatest concerns is that those companies that either own prefabrication facilities now or are considering them do not spend enough time analyzing their costs, savings, productivity and other important measurements that would help justify increasing use of prefabrication or other strategic decisions. From our work in the field as well as our research, we find that those who make decisions about the use of prefabrication and modularization part of their strategic planning will fare better in the long run. Those are the companies that are less likely to take half-measures. If they find a competitive advantage in their markets for their prefabrication capabilities, they will act accordingly and get smarter on how to make the shop a profit center and advantage for getting and doing work.

As everyone in the industry realizes, prefabrication is not new. Mechanical and electrical contractors have had shops for a long time. Nevertheless, things are changing. Those shops should now be employing the best of new technologies, including BIM and automated equipment. How to organize those shops and labor for the best results should be high on the list for productivity improvements and training for managers and also stakeholders

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