

Discussion of production 'theory' best fits in the construction industries with highly efficient in terms of their production and environmental impact.

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Abstract: Construction business holds prime importance for the economy of any country due to its high level of contribution to GDP. There have been a number of revolutions in the industry over the past few years. With the introduction of newer methods and advanced technologies, the approach that is followed has had a number of major changes and modifications. This report explores various trends in the construction arena and makes an attempt to understand how modern building production impacts the environment and the tradeoffs that are made while choosing between the best production method for construction and sustainability of the building.

Key words: Traditional methods, Modern methods, Environmental Concerns, Unique products.

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Chapter:1

1. Introduction

Building and construction has undergone a lot of transformations over time(1). Early buildings were constructed using less durable materials. Modern construction today uses prefabricated materials that are produced off-site. There are concerns on quality control in the production of materials used in the construction(2). Traditional designs and methods on construction failed to address issues on the impacts of construction on environment(3).

Construction has been suffering from production inefficiencies from long in traditionally produced building but with application of production theory used, some of these concerns could be

addressed. However, the actual potential of the production theory in resolving issues has to be explored in depth.

Modern day building production methods involve plethora of technological equipment and also demand the project completion within deadlines adhering to quality standards. As compared to traditional construction methods used for building projects, there are some modifications and new methods that are being used in the construction of modern buildings and the same would be explored here.

Traditional construction methods have been considered the most effective for the past years. Managing projects under traditional method was very simple since most activities were done at the

same place. Although many contractors, designers and clients are opting to modern construction methods, it is evident that less change has taken place in terms of the effectiveness. Currently, there is debate about the best construction method to undertaken(4). More attention is drawn to the impacts of construction method to the environment and waste management(5).

To withstand the current competition and rising cost of construction, designers and clients are striving to come up with more unique structures. This paper compares the traditional and modern methods of construction and tries to establish how the modern construction projects are unique.

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2.1. Traditional Production Method

Over the past years, there have been changes in the technology and economic needs in the society(6). These changes have greatly affected the construction methods, designs, and developments in the construction industry. The continued change in the economic, social, and technological needs and requirements has led to the emergence of new construction materials and buildings. The traditional production method was where locally produced materials were used in the construction(7). This was part of the informal sector of the building industry, where non-professional builders

were involved in the works. It was major characterized by the wide use of locally available materials, the adaptation to the local environmental conditions. The production methods were designed to utilize the locally available materials(8). The aim was to produce products that will give adequate standards of performance. Mass production method was the most commonly applied technique since there was no need to come up with unique products. Traditional methods had no quality control system set up as a result constructions were carried out without any formal methods of quality control(9). Production management in this case was affected by bureaucratic systems or less developed management policies. These activities were majorly carried out in-situ. It was until the end of the Second World War that the need to consider the methods that would provide suitable materials and labor in the construction of new buildings(10). There have been changes in architecture and design that involved modifications to the layout of structures and increasing spans for both roofs and floors. Most factories produced the required materials using the mass production method and become the major suppliers of the materials to the customers(11).

Over the past few years, production managers have been struggling to choose the production methods to employ in the companies. In

fact, integration of the production methods available, technological change and the production models to address the need of uniqueness in construction has been a major challenge to production managers. Several production methods and models try to address how uniqueness can be achieved in construction. These theories revolve around the traditional project management and product methods and the modern production methods.

In traditional methods used for construction of buildings, full concrete was produced at the construction site and the same was then left for 28 days for hardening and only after it was hardened, floors were primed and then levelled. This process also required a number of prerequisites that have to be completed including, lift shafts, waste pipes construction and pipe conduits for electricity. A huge number of equipment were required at the site for priming and compounding that had to be transported from far places, and thus, construction could be hugely affected by weather conditions that may not allow transport or cause hurdles in site construction.

Raising of walls used to take around 45 days to finish and only after that the remaining construction could be followed. These methods had several risks and disadvantages such as damaging of mould if concrete didn't dry up, material release caused by poor C value of levelling compound, trapping of moisture

inside concrete after priming, long drying times, extra site work, high logistics and material costs (Asme.org, 2013).

2. 2. Advantages of Traditional Method

2.2.1 Communication Channel-

The structure of communication channel is outlining in a way that both formal and informal communications flows effectively without any hindrance. In traditional method of production, there workers and managers have their levels of responsibilities.

2.2.2 Cost control-

The traditional method ensures that the projects are completed within the allocated budget. This is made possible through a wide labor base; this ensures that the allocated time limit is met. Traditional construction method helps in solving the problem of cost minimization. In addition, the attempt to provide unique products in a competitive sector proves to be difficult. However, in the case of batch and mass production, the cost minimization can be achieved enjoying economies of scale.

2.2.3 Efficient Method –

One of the advantages of the traditional method is its efficiency in the production of the desired products. This helps in satisfaction of the client's needs and production of the unique buildings and structure. Traditional methods, therefore, help in achieving the construction companies to attain goals and objectives. This in turn leads strengthening of the

bond between the professionals, designers, and clients.

2.3. Limitations of Traditional Method

Traditional method also has various limitations, which affect its application in the modern construction sector. Lack of commitment and poor coordination has led to under performance. This makes clients have less trust to the structures built by the contractors hence unmet client satisfaction.

There is a serious struggle to execute all the outlined activities within the given timeline in the traditional methods of construction(12). This has been evident by top managers paying much attention to the activities that matter to them. In addition, conflicts occur between top managers due to lack of customer focus in their decision making process(13).

- As the construction was fully happening on the site, the work was often affected by severity of weather conditions
- Traditional methods took too much time to complete construction
- The energy consumption in traditional buildings was huge because of the production methods and types of materials used

- The traditional buildings were not constructed with much considerations about their environmental impacts and energy usage

Chapter:3

3.1 Modern Production Methods

3.1. Transformative Flow Value Method

This method tries to address the management of the three fundamental principles of production. It holds that in production, the transformation, flow of production and the value addition views must be balanced to bring out a unique outcome(14). It calls for the three views, that is, modeling, value addition, and transformation to be attentively monitored while carrying out production, construction in specific. The methods bring more practical contributions of the production methods to production of quality outputs and use of the advancing technology. It is widely observed that, due to variability of production methods in construction, intended task management degenerates into mutual adjustment by teams on site. Previous research shows that there are management problems associated with client decision, design management, and construction management. It is

therefore possible to do away with no site work by use of prefabricated materials. The use of technology in construction, like the 3D design, Last Planner and other construction automation techniques can be used reduce the time interval between different activities so to produce the desired qualities of products. This theory is relevant to the production methods used in the construction industry since professionals to address the current dilemma in the industry can use it(15).

3.1.1 Lean Method

Lari Koskela put this theory forward in 1993. He argued that construction industry would benefit much from adopting the basic principles, technological advancement, and the lean manufacturing technique(16). According to Koskel, the adoption of these new approaches will help the construction companies eliminate the inefficiencies arising from replication, many waste, and inefficient methods of production. Adoption of the lean manufacturing theory in the construction industry will help the professionals integrate the use of technology in the management of construction projects. Since production, management is concerned with the planning, resourcing and

controlling of the processes and procedures, which are involved in converting raw materials into the finished products, and the delivery of products to clients and customers. It can also be applied in the modeling and designing of building structures. As a move to improve labor productivity, reduce wastes and inefficiencies, and reduce cost of construction, a combination of basic principle, technology and lean thinking can help professionals achieve this and satisfy the need of their customers.

Construction companies can also partner especially between contractors and subcontractors to carry out their activities like production of all, or a percentage of, their building projects for a set time(17). A group of subcontractors is retained for a duration longer than just one 'one-off' construction contract. The client benefits from the partnering approach by acquiring a team which will come to know their business and their construction requirements very well.

3.1.2. Off-Site Production

The TVF theory can be linked with the off-site production method that undergoes the process of structural designing, fabrication, and transportation of materials. This is because there is greater

quality of materials produced and faster rate of work and general efficiency. The construction method includes use of technology and innovation in the fabrication, manufacture of several building materials. Integration of several optimized systems and inputs leads to the quality in designing, prototyping, and general uniqueness of out the built structures satisfying the customer needs. Project managers and professionals can use the method to bring improvements, value and transformation to their products while still keeping the teams intact which in turn bring more productivity to the their construction companies(18). It employs Batch Production where standardized units of materials (batches) are produced to be used in the construction industry. It is very easy for managers to control the activities since they are specialized on specific products.

3.1.3 Precast concrete

In modern buildings, pre-cast concrete construction blocks are being used such that the components of buildings could be separately produced in factories and then the same were assembled at the construction site to construct building. This method

has several benefits for the construction industry and for society such as reduction in costs, lesser inconvenience to neighborhood and fast construction processes.

One method used for making pre-cast building blocks involves creation of hollow forms and filling of sand inside at the construction site. Another method used on construction sites is the use of in-situ concrete in which instead of sand, a liquid is poured into forms at the construction site.

Some of these methods make way for construction of unique infrastructure at the cost of environmental impacts while others also make a consideration of sustainability of building in addition to the appearance and modernization of construction. Some of the new trends observed in the construction arena include:

Single Design Model: There is a shift from a model to every single phase involved in engineering and construction to a single model for the entire design. It leads to better co-ordination and also results in major savings related to the time and money.

Materials: The approach of usage of materials and the choice of the same has also seen some of the major changes in the recent past.

For instance, more energy saving and environment friendly material are being used for construction projects in modern buildings now.

Energy Efficiency: Energy consumption is given special attention while executing construction projects. Production methods can be used in modern buildings for improving environmental conditions at a global level.

Permanent Modular Construction: Modular construction is the popular demand of customer looking for flexibility and ease of application. It provides the capability to build and expand later on rather than building all at once. Modifications are also easy to implement in such type of construction (Asme.org, 2013).

However, considering the environmental concerns raised by the construction industry initiatives, it would be important to understand how these new methods of construction can impact the environment and sustainability aspects in construction of buildings. A method called revegetation of concrete has been used on projects for reducing the environmental impacts of these concrete productions.

A study has explored how this method has affected the environmental impact of construction in case of a precast retaining wall which could be useful in understanding the potential of the method. Revegetation method involved production of hollow precast concrete boxes that are filled with soil at the construction sites. The study had found that environmental damage cause by the retained wall using this method was 35% lesser than the retain wall that was constructed using ready-mixed concrete. The benefit is not only seen in the environmental protection but also for the construction business as the costs of concrete production was also reduced because of the use of hollow significantly(19).

3.2 Advantages of Modern Methods

Meeting of Customers' Needs in the modern methods of construction, customers have the opportunity to outline their specifications/needs. The project is outlined in such a way that each activity has some one monitoring the activities. This leads to production of unique products enhancing customer satisfaction. The method is therefore considered very effective in achieving the customer needs.

Well-organized process- Modern production methods are well organized into phases. Each phase has a time limit and cost allocated to. This helps in achieving high quality construction

products as well as full utilization of the resources.

- As buildings are constructed in-situ with blocks produced in factories and then assembled at site, the construction becomes fast
- Modern methods have been developed considering the sustainability aspects there were missing in traditional buildings
- In modern methods, the construction projects use modern technologies like BIM that allows project teams to understand the sustainability of building even before construction so that best design can be formulated before actual construction begins.

Some Modern Construction methods like Building information modelling and others can be useful in various ways such as fast construction, energy saving and so on.

3.2 Limitation of Modern Methods

The key goals of project managers, professionals, and designers are to implement production theories in the construction industry. This is aimed at reducing the inefficiencies, wastes, and high cost of construction(20).

However, there have been several challenges that affect the implementation of these theories. These have resulted to continued customer non-satisfaction and risks of losing the profits and potential customers. The challenges include; Variability in Customer needs- In One-Off production method, every customer has a unique need to be satisfied in terms of design, time limits, and materials to be used in construction. Meeting all the customers' needs may involve the use of modern theories of construction like the lean manufacturing. However, the use of one theory alone may control one aspect, like waste minimization output quality but may be unable to control cost(21).

Chapter:4

4.1 Discussion

4.1.1 Building Information Modeling
Building Information Modelling has been adopted slowly by the construction industry as the technology was earlier very complicate for adoption. However, with increasing development in the arena has somewhat simplified the adoption and usage of BIM. BIM design capabilities make it possible to do engineering analysis of every characteristic of a construction assembly including physical characteristics, operational

characteristics, fabrication requirements, and thermal behavior.

With this analysis, products can be made more efficient with modifications and at the same time, they can be made more stylist and suitable to the purpose of construction. Moreover, the building design can be optimized with the information obtained through integration of construction processes using BIM tools such that various design options can be explored to arrive at the best option in terms of its ability to fulfill all requirements of the building and at the same time, keep the building sustainable(22).

Sustainable building design is one major benefit that can be realized with the use of BIM for construction projects. LEED (Leadership in Energy and Environmental design) is a green building rating system that has been widely accepted, and LEED certification has been pursued by many building owners. LEED specifies green requirements in five categories that are required to be satisfied to be able to call a building green. These include site design, quality of indoor environment, energy efficiency, material usage and water. BIM models like Revit contain a significant amount of information and possibilities in gaining LEED certification which makes this technology solution attractive to many builders (22).

4.1.2 Resource Saving

Energy and materials are the key resources used in construction of building or other infrastructure, and if these can be minimized or saved in modern buildings compared with traditional construction methods, it can improve both the construction and use of building. RERM has highlighted in a study involving construction sector that better construction and building usage can significantly influence the energy consumption to the extent of 42%, CO₂ emission to about 35%, and material extraction reduction by 50% and water saving of around 30% (23).

RERM has defined some milestones for improvement in building construction aiming at increasing resource efficiencies. The approach involves the use of life cycle approach to building construction such that nearly zero-energy buildings with high levels of resource efficiencies can be constructed. The approach suggests 2% per year of refurbishment of building stocks and making use of 70% of construction material that is non-hazardous and waste resulting from its demolition can be recycled(23).

Despite good number of advantages, there are some challenges in modern construction methods:

- Modern construction requires more efficient and skilled staff

to manage the project efficiently

- As the blocks are manufactured in production units, when they are put to construction sites, there could be gaps caused because of design inefficiencies leading to trapping of water inside making buildings weaker
- Many modern buildings are constructed using material like glass and wood that can be more easily dilapidated than cement and bricks making building more susceptible to environmental and other accidental mishaps.

4.1.3 Reluctance in Professionals

While other industries have been openly adopting ways to reduce CO₂ emissions and energy consumption, the construction sector has been reluctant in applying energy saving principles and methods because of fragmentation and both internal and external challenges such as lack of collaboration between suppliers and contractors, insufficient knowledge transfer between workers and so on. However, the sector does have a potential for improvement which can be made using innovative construction technologies and energy saving methods(24).

In modern scenario, technologies have come up that can reduce this energy usage of building during its complete construction life cycle. Some of the approaches taken include having shared responsibility for energy reduction between different parties to contract and changing behavior towards keeping improvement of energy efficiency on priority. However, these methods are mostly people driven and not feasible with proper involvement and collaboration.

Other methods that have been formulated aim at consumption of zero net energy in building which is a visionary thought but has given rise to several initiatives such as use of more energy efficient equipment for construction, production of energy through a renewable resource and sharing of energy using intelligent grid infrastructure to minimize consumption(25).

Council House 2 in Melbourne is one such building that has used several technologies for reducing the energy consumption in the building. These include use of undulating high thermal mass concrete material in ceiling, use of photovoltaic cell for illumination of facade, solar panels on roof tops for heating, glare control, green roof, solar shading and so on. With these methods adopted, the building could reduce 82% of electricity, 87% of gas

consumption and 72% of water supply from mains as compared with past construction.

Building Information Modeling is a technological innovation which has again been adopted on certain construction projects leading to tremendous benefits in terms of reduced energy consumption and CO₂ emissions. However, some internal business challenges faced by construction organizations make it difficult for them to adopt BIM in practice. For instance, due to lack of innovation in construction technologies and construction businesses find it difficult to adopt new technologies for construction. Further, there are inconsistencies in processes adopted by construction companies, and the processes are not matured enough causing delayed adoption. Other reasons of lack of adoption of sustainable infrastructure technologies can be weak monitoring of construction projects, lack of cross-functional collaboration, conservative culture of the construction organization, shortage of talent and so on.

Chapter:5

5.1 Production Theory – Best Fit for Modern Day Building Production Methods

The methods of constructing buildings have changed overtime. While

traditional methods of construction focused on the construction in-situ and all other stages in the construction process has to depend on the previous process, the modern method of construction focuses on off-site construction, where materials are produced away from the construction site.

Modern and traditional construction method begin at the stages(26), that is from the project planning, design to the execution of the plan on site. However, modern construction method makes it possible for the project activities to go on consecutively both onsite and off-sit. There is use of modern prefabricated materials with high quality standards as opposed to the traditional materials used in the traditional methods that did not meet the quality standards.

Modern method of construction is applying technology in the design and manufacture of materials to be used in the construction process. This has helped to solve the negative effects of construction to the environment. In addition, the use of modern technology to prevent the impacts of weather on the construction process is efficient. The modern construction method is therefore considered unique.

Production Theory – Best Fit for Modern Day Building Production Methods
Theory of production refers to the set of procedures that are followed in a sequence. An efficient theory of

production should form a link between the planned actions and the set of objectives that are defined for a particular project. There are three basic steps identified in production theory:

- Design
- Control
- Improvement

Goals of the theory of Production are:

- To produce the goods as per required specifications provided by a client.
- Cost constraints are required to be maintained with optimum level of utilization.
- To meet non-functional requirements for the customer in an efficient manner ensuring reliability, flexibility, durability and likewise.

Production as Transformation

The best suited theory which can be applied to building production is Walrasian Production Model. As per this theory, the success of a project is determined by understanding the link between production factors and the amount of production. The model represents the phases in the form of P-graphs which comprises of:

- Assemblies
- Sub-assemblies
- Components
- Sequence of operations

Other generalization of this theory considering modern building production and architecture is based upon the R-graphs. R-Graph explains how the resources must be taken care of and allotted groups, departments, and factories. Capabilities and capacities may also be defined accordingly.

A third generalization of this theory categorizes control model and activities into three parts as follows:

- Management of resources
- Management of products
- Co-ordination and synchronization of the various entities

Mass production is the need today considering increasing demand for buildings and faster construction

Comparison scenario at a glance: -

Sl. No	Production method	Cost/Price		Design	
		Price certainty	Fee Levels	Multiple work suitability	Var uit t
1.	Traditional	Very Good	Medium	Not suitable	Good
2.	Modern method of Production	Very prominent	Average	Suitable	Not suitable

Table 1: Compression chart of production method (27)

5.2 Debate on Best Fit Production Theory

Production theory views the process as transformation from inputs to outputs, and this transformation is decomposed into elementary tasks. This transformation is further seen as a flow that includes different stages. The theory also conceptualizes production as a method used for addressing needs of consumers such that these needs can be transformed into a design. This theory can be applied to the construction projects to gain efficiency in construction. These conceptualizations used for building production has resulted into development of a Transformation-Flow-Value (TFV) system.

When applying the theory to construction, various tasks that are identified are actually the assemblies. Considering flow, every task can be accomplished by maintaining 7 resource flows. When comparing building production with other manufacturing units, former processes show more variability in resources(28).

The production done for the construction industry uses assemblies. For instance, in the construction of a residential stand-alone building, there are a number of rooms produced that are integrated to form a single structure. For producing window, the structure is designed and created in

the window construction factory. It is then shipped and transported to the construction site. It is then the responsibility of the site coordinator to transfer it to the installation team for installation. The building then proceeds to assembly.

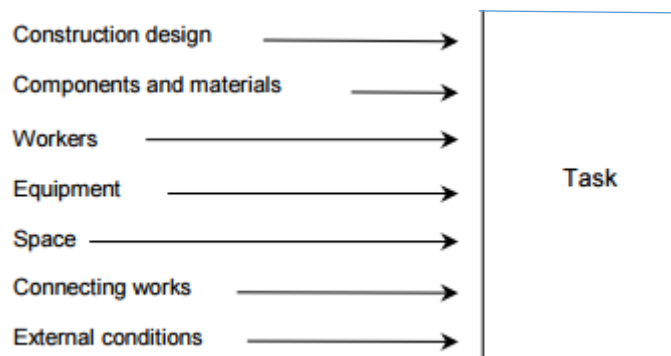


Figure 1: Basic components in a Construction task for modern building construction (P., et al., 2015)

The administration in a production unit uses a specific production process but due to variability of production, proposed undertaking results require some changes. Thus, different techniques are used by administration to avoid the unfavourable effect of variability on assignments.

Along with the theory of production, production management is now introduced in the construction projects in order to streamline the various tasks that are associated with the design, control, and improvement of the building system.

5.2.1 Impact of Construction on Environment

The world population is increasing drastically generating more demand

for living space. In urban areas, the increase in population is almost 200,000 people per day and this population requires affordable homes, transportation, and other utility infrastructure. However, with increasing construction projects, there are trade-offs concerning environment. Building construction industry is the largest contributor of green gas emissions and by 2030, this figure is expected to double(29).

Building contribute to at least 40% of the energy consumption in most of the countries today and with increasing construction projects, this figure is further on rise causing risks to climate and biodiversity. It has been discovered that 6 countries including Brazil, India, China, Japan and United State together contribute to over two-third of the world's energy demand.

Most of the energy used up in construction sector in these countries is generate by non-renewable resources causing large amount of CO2 emissions. Materials that are used for construction increase the danger as they are highly energy intensive. The energy is spent on extraction of raw materials, their transportation, and manufacturing of the building materials which adds to an initial embodied energy.

Material	Embodied Energy (MJ/kg)
Solid Concrete Blocks 40cm x 20cm x 15cm	0.286
Hollow Concrete Blocks 40cm x 20cm x 15cm	0.374
Solid Concrete Blocks 40cm x 20cm x 10cm	0.424
Hollow Concrete Blocks 40cm x 20cm x 10cm	0.564
Laterite Blocks	0.032
Burnt Clay Bricks	0.813
Mud Blocks	0.007
RMC M25	1.304
Paving Tile	1.005
20mm Aggregate	0.209
12mm Aggregate	0.167
6mm Aggregate	0.279
Manufactured Sand	0.105
Quarry Dust	0.167
Roofing Tile	1.45
OPC	7.36
PPC	4.09

Figure 2: Embodied Energy in Building Materials(P., et al., 2015)

When building materials such as concrete, clay, cement, bricks, aggregate, hollow, mud blocks, roofing tiles, and other building blocks are used in large quantities, a huge amount of initial embodies energy is produced. A study acknowledges the usage of energy by each of these materials that collectively form the embodied energy consumed during the construction life cycle such that the same may be used to compute the total embodied energy trapped in construction material management processes. PPC, OPC, Roofing Tiles and RMC give the most contribution to this energy(30).

Choice of these building materials can thus be made in a way to reduce embodied energy in a building if improvements have to be made thereby making the building more sustainable for the environment. Some of the criteria that may be considered for the choice of the building material in such a case can be reusability, recycling, non-pollution, local sourcing, lower energy, renewability, lower CO₂ emission and least wastage generation. For instance, wood is a renewable material that fits to most of these criteria and thus, may be used for constructing sustainable buildings. Further, waste wood may also be used for generation of fossil fuels which could be much more cost effective and energy saving than recycling of metals and glass used as building material(31).

Chapter:6

Consideration

As per the table 1, despite the fact that traditional methods of construction being efficient in production of the construction products, there is still need to adopt the modern methods of production in the construction sector. This is because modern production methods embrace the use of modern technology and design methods in construction. Modern methods have the capability to address the environmental and

commercial concerns in the sector. It can also help in prevent factors that negatively affect the quality of the construction products. Comparative analysis of the two methods of production used in construction, therefore, reveals that the modern method of production has some distinctive characteristics that can help produce unique products compared to traditional methods. Modern methods of production lead to gives unique construction of projects.

Chapter:7

Conclusion

The paper explored the trade-offs between the production in building construction and its impacts on the environment. It was found that the modern buildings are being constructed concerning environment on many projects, but trade-offs have to be made on modernization demands

Traditional production methods are very efficient in construction since there was a wide application of in-situ method, where all the activities were done on site. This method, have been affected by factors like changing weather conditions which influenced the quality of materials and products used in construction. It failed to address the changing management needs like resource, quality control, and time management. The modern production methods make use of the prefabricated materials in construction.

The development of these improved techniques in construction methods not only address the current health and safety concerns but also proves to be very efficient in production. Lean method is very important since it has helped to improve quality of building designs. Off-site construction makes it possible skilled staff to ensure that quality standards are maintained. This will ensure that the final design and product specifications reflect customers' requirements and needs. To promote building practices that will enable control of construction costs, structural safety, production quality raw materials and other intermediate products then professional designers and clients must adopt the modern production methods in construction. The prefabricated materials deliver high quality products that contribute to achieving the unique product goal. These materials also demonstrate a high environmental best practice and high efficient products compared to the traditional products. Although, there are limitations of the use of the modern methods, the existing literature encourages

the adoption of the modern methods. This will help build more safe, quality, and unique structures that will satisfy the clients' needs. Thus, more organizations

are likely to adopt modern methods of building production in coming years.

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