# APPLICATION OF LEAN CONSTRUCTION PRINCIPLES IN AFFORDABLE HOUSING IN INDIA

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**Abstract:** *The idea of integrating Affordability with Lean construction techniques itself is an innovation. In India we experience vividness and variety in all fields from science to cultures to tastes and communities. Housing is one of the most basic needs of survival. At the same time we are facing an enormous depletion of our natural resources due to vast growth of population and unawareness among the users. Here comes the concept of Lean which relates directly to sustainability. All those materials, methods, techniques and practices which decrease the human efforts and at the same time reduce waste and utilise all those materials which enhance the sustainability and cost effectiveness are considered Lean. The idea of the propaganda of lean is to implement a whole new concept of 'changed thinking into lean thinking'. Lean begins from the mindset and ends up into final results. These two are basically the two supporting pillars and everything in between is considered as the ladder steps. 'Lean' is not just a word rather it is a concept in itself. This concept although has been used since ages yet much needs to be incorporated in the real world and understood by the end users so that the idea behind successful implementation and achievement of sustainability and affordability is justified.*

***Keyword****:* Lean Principles, Affordability, Sustainability, Lean thinking, Waste optimisation, Last planner system, Value Stream mapping, Lean construction materials.

## 1. INTRODUCTION-

India, like most major emerging economies, has been witnessing accelerating urbanisation. As per the census of India in 2001, about 72% of the population lived in rural areas, and 28% in urban areas.
By 2011, these figures had changed to 69% rural population and 31% urban population. In fact, as per census 2011, for the first time since India's independence, the absolute increase in population was more in urban areas than in rural areas. According to estimates, around 600 million people are expected to make urban India their home by 2031, a whopping 59% growth over 2011. As an increasing proportion of India's population starts participating in its growth story, it brings with it mounting pressure on the existing infrastructure, which needs to at least keep pace with the growing demand, if not be ahead of the curve.
The current housing deficit in India stands at 19 million units, which, in the absence of any meaningful intervention, is slated to double to 38 million units by 2030. 95% of this deficit is around the EWS (Economically Weaker Sections) and LIG (Low Income Group) segments, which technically puts the figure at a staggering 18 million units in this category (approximately). While this number is huge, there is also a substantial chunk of upper end of LIG band and lower to middle end of MIG band, which we can say comprises 'the emerging middle class' who are also deprived of decent living conditions.
Nowadays, The Toyota Production System is known all around the World as a manufacturing management method and a lean construction and management tool to reduce waste during the production and increase the final product quality and value. The TPS is now understood as more than simple tools and management approaches, and it is described as the Toyota Way, a definition that encompasses all the philosophy behind the TPS. This philosophy started to be constructed since the early foundation, in the late 1880s, by Sakichi Toyoda, as a family business (Liker, 2004). Sakichi had a spinning and weaving machines business, and improved the systems by trial-and-error approach, moulding the concept of getting the hands dirty as a way to understand and improve the production, which is an important concept.

### 1.1. The most widely accepted Lean Principles are-

a) Eliminate the waste.

b) Precisely specify value from the perspective of the ultimate customer.

c) Clearly identify the process that delivers what the customer values

d) Eliminate all non value adding steps.

e) Make the remaining value adding steps flow without interruption

f) Manage the interfaces between different steps.

g) Let the customer pull – don't make anything until it is needed,

h) Make it quickly.

i) Pursue perfection by continuous improvement.

j) Do not push your projects on customers.

**1.2. Problems in implementing lean construction techniques-**

- Lack of awareness among people about the application of lean construction principles and techniques.
- Lack of successful and established examples of the implementation of these principles in Indian construction industry.
- Cultural hurdles like reluctancy among people to give up the deep-rooted techniques and methodologies as well as hierarchical tendencies.
- Restrictions in the planning process and lack of consultancy.
- Lack of a trained, committed and reliable labour force with technological awareness and modern skills.

**1.3. OBJECTIVES-**

The objectives of undertaking this topic are to make the construction industry aware of the advantages of responsible and efficient application of lean thinking, lean principles and lean construction techniques thereafter. Not only in India but in all the other countries as well construction is an emerging sector. With an emerging population there has been a sudden urge of constructing large number of houses on the one hand while rapid urbanization is leading to the development of industrial sector at a very fast pace on the other hand. Not all the people are in the economic conditions to afford a high standard of living and there emerges a need of construction affordable houses. Government of India passed this scheme of constructing affordable houses for all my 2022. Millions of units are in deficit and hence this construction would require certain out of the box techniques and methods to be implemented for its success.

**The objective is to focus on-**

1. Application of lean construction principles to the entire process rather than the output.
2. Proper implementation of all the possible ways to increase productivity and decrease the cost.
3. Internal Management system should be guided for proper implementation of these principles.
4. Change in the outlook of people towards the "CHANGE" we are trying to make.
5. Training of the staff and labors.
6. Introduction of mandatory guidelines towards the implementation of lean construction

**2. DATA ANALYSIS-**


(All the lean principles suggested in the study)

The above mentioned techniques are all those which have been suggested to be implemented during the design and construction of affordable housing units in order to attract maximum customers and hence generate maximum profits. These techniques are most suitable to be implied in Indian construction industry specifically in lucknow (U.P.) as per the research carried out and outputs derived from the builders which were interviewed during the study. Each of these techniques have been described vividly and comparisons have been drawn to signify their importance over the traditional techniques which have been in practice since age.

## 3. WASTE OPTIMISATION AND REUTILISATION ON THE SITES-

In defining "Lean Production" principles, waste is defined as- "any inefficiency that results in the use of equipment, materials, labour or capital in larger quantities than those considered as necessary in the production of a building". It includes the categories such as waiting time, unnecessary transportation, non value added processing, excess inventory, rework, etc.

OR

"any loss produced by activities that generate direct or indirect costs but do not add any value to the product from the point of view of the client".

Thus, according to lean principles, construction waste can be broadly divided into three major categories:

- Material
- Labour
- Equipment

However, material wastage is of more concern because most of the raw materials from which construction inputs are derived, come from nonrenewable resources. Also, concern has been growing in recent years about the adverse effect of the waste of building materials on the environment.

Measuring waste is an effective way to assess the performance of production systems because it usually allows areas of potential improvement to be pointed out and the main causes of inefficiency to be identified. As far as it is known, there has never been any systematic attempt to observe all wastes in a construction process. However, partial srudies can be used to indicate the order of magnitude of wastes in construction.A wide variation due to local conditions, project types, construction methods, etc. may also be anticipated. In general, a very high level of material waste is assumed to exist in construction.

### 3.1. Material scrap waste(W)= [ (Ma * Mt)/ Mt] * 100

Ma = actual waste
Mt = theoretical waste

### 3.2. MAIN CAUSES OF WASTE-

**Reinforcement**

The main reason for steel reinforcement waste is some short unusable pieces produced when bars are cut. It was observed that the worst performing sites were usually the ones in which the structural design was poor in terms of standardisation and detailing, causing waste due to non-optimised cutting of bars.

**Cement**

Analysing the waste of cement is relatively complex due to the fact that this material is used as a component of mortar and cast in place of concrete in several different processes, such as brickwork, plastering, etc. Much waste of cement was observed in the production of mortar on site. In-situ production of mortar and concrete increases the wastage of cement because cement and other materials are loaded manually in the mixer using inadequate equipment. The production of brickwork was also responsible for some waste of cement, due to the excessive consumption of mortar in joints. The excessive thickness of plaster was identified in some of the sites as a major cause of cement waste.

**Aggregates**

The main causes of cement waste can also explain most of the problems related to river sand and coarse aggregates. Sand and aggregates are usually delivered in trucks, and so there may be additional losses related to the lack of control in the delivery operation and the necessary handling it demands. In recent years, many companies in India have started using packed, ready to use mortar mix and ready mixed concrete, which will eliminate many problems related to delivery control, handling and transportation. Insufficient planning of the site layout, lack of properly maintained pathways, and the use of inadequate equipment were among the main causes of waste.

**Bricks/Blocks**

In most poorly performing sites, a combination of causes were related to the waste of bricks and blocks. At several sites, there were problems related to the delivery of materials, such as the lack of control in the amount of bricks or blocks actually delivered and the damage of bricks or blocks during the unloading operation. It was observed that the poor handling and transportation were the major sources of waste for bricks and blocks. Another source of waste was the need to cut blocks and bricks, due to the lack of modular coordination in the design.

## 4. MATERIAL WASTE MINIMISATION

Minimising waste in construction sites will lead to increase in the overall project performance. Various improvement measures can be adopted to minimise each type of waste. For the purpose, interviews were conducted with construction industry experts to get their opinions for minimising waste at construction sites. The industry experts include 3 project managers and 3 planning managers from the projects studied. Although level of material waste was found to be low, much of this waste is predictable and avoidable. Waste minimisation can only become effective if proper documentation is maintained and corrective actions are taken to achieve continuous improvement. Indeed, very few of the sites involved in the study had organised records on the actual delivery, storage, and consumption of materials. Various improvement measures suggested by the industry experts for minimising material waste are given below:

## 5. LAST PLANNER SYSTEM-

It's full name is the Last Planner System of Production Control. Production control is necessary on projects to support working toward planned accomplishments, doing what can be done to move along a planned path, and when that becomes impossible, determine alternative paths that accomplish desired goals. The term Last Planner® is a registered trademark of the Lean Construction Institute, which is why the "®" symbol should appear when first used in a document. The Last Planner is a holistic system, meaning that each of its parts is necessary to support lean project planning and execution. Resist the temptation to treat the system as a menu from which you select only the parts you want to use.

The system is organized into five major parts-

- MASTER PLANNING
- PHASE PLANNING
- MAKE READY PLANNING
- WEEKLY PLANNING
- LEARNING

### 5.1. Last Planner principles-

- All plans are forecasts; all forecasts are wrong.
- The longer the forecast, the more wrong it gets.
- The more detailed the forecast, the wronger it is.

The implication of these principles is that it is important to-

- Plan in greater detail as you get closer to doing the work.
- Produce plans collaboratively with those who will do the work.
- Reveal and remove constraints on planned tasks as a team.
- Make and secure reliable promises.
- Learn from breakdowns.

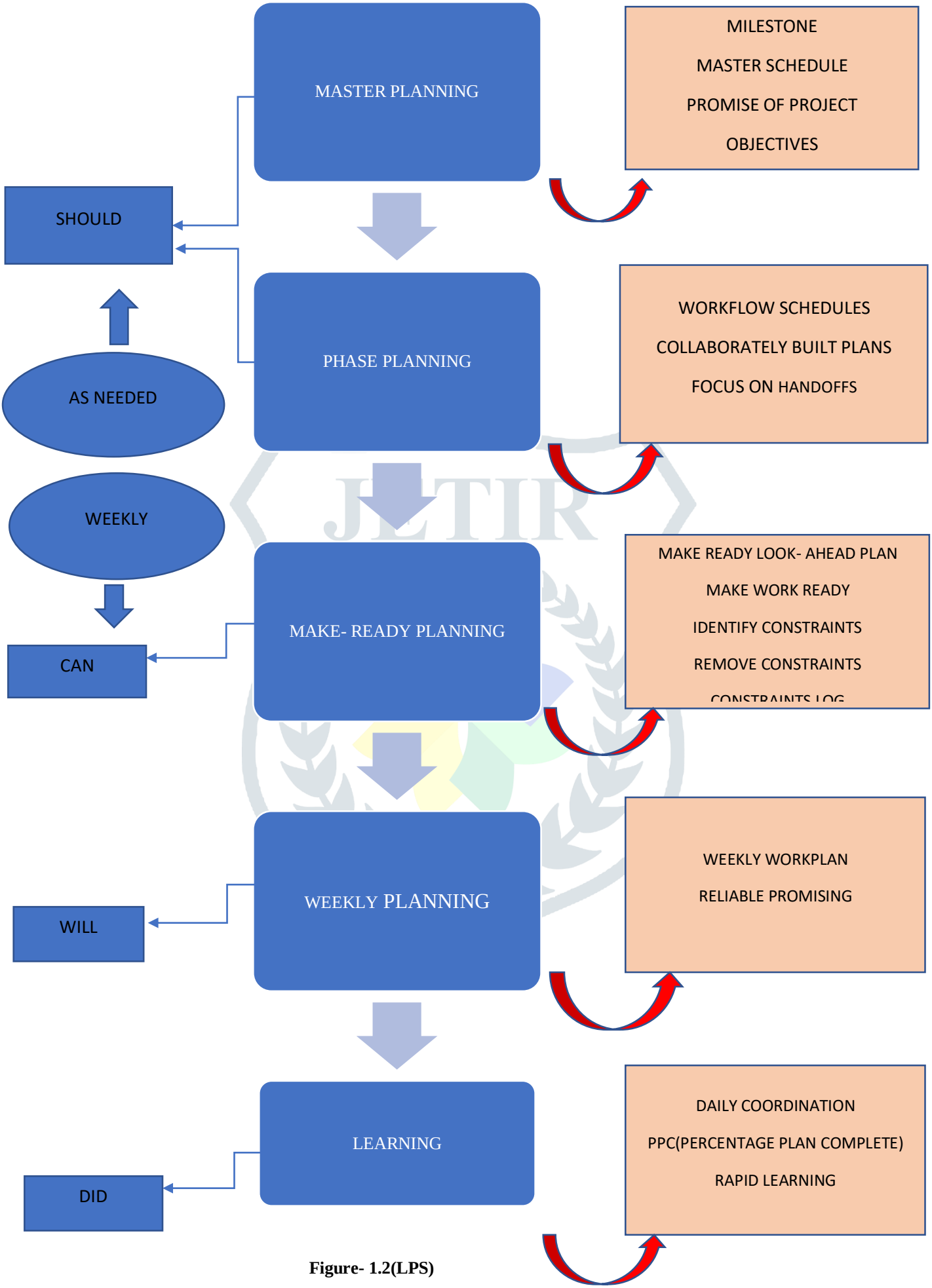



**Figure- 1.2(LPS)**

The first two parts focus on identifying the work that should be done to complete a successful lean project. Master Planning, part one, is done at the very beginning of a project. The master planning work is focused on identifying major milestones that help gauge the pace at which the project will progress if it is to be successful. Normally milestones are completion dates for each of the major project phases and dates for releasing the purchase of major long lead building items. Ideally both design phase and construction phase last planners participate in developing the master-planning schedule. The term "last planner" refers to the people on the team responsible for making the final assignment of work to specific performers and ensuring they have the materials, equipment and information available to complete their assignments. During the design phase, last planners are typically architectural and engineering project managers. During the construction phase, last planners are typically foremen and superintendents for the trade contractor crews.

Phase planning, part two, is done two to three months before the beginning of each phase. Phase in this context refers to a portion of the project that makes sense to consider as a complete unit. The phase breakdown for a project will depend upon the size and complexity of the work, with beginning and completion milestones for phases identified during the master planning. Phase planning develops an agreement between last planners on how all the work between those two milestones will be completed within a stipulated period of time.

The third part of the Last Planner System focuses on ensuring that work can be done. It is the make ready planning through which last planners look ahead to evaluate whether there are constraints to upcoming tasks identified during phase planning. Most teams look ahead six weeks when make ready planning, though on complex projects a longer time horizon may be warranted. A lookahead plan is used to help the team focus on which tasks need to be made ready first (priority tasks) in order of priority as per planned by managers.

Constraints are identified on a log, with responsibility for removing a constraint identified along with a promise for removing each constraint by a certain date. Insufficient make ready planning is often the single most factor in project workflow breakdowns, so it is vital that the team attend to make ready planning in a diligent manner. The make ready planning also includes the refinement of tasks identified during phase planning into more detail by dividing it into smaller segments, as the work is better understood.

The fourth part of the Last Planner System focuses on what each last planner will do to fulfill the promises made during the phase planning. This is accomplished through the preparation of a project Weekly Work Plan, wherein each last planner identifies the tasks their teams will complete each day of the following week. Reliability on the techniques and process is extremely important in developing these shared plans.

The fifth part of the Last Planner System focuses on learning from what the team did. Learning is a daily action for lean project teams. Last Planner provides two specific opportunities for learning. One is through the daily coordination meeting, often called the daily huddle. In this brief stand-up meeting, last planners confirm whether their teams accomplished the planned work that day, and if not agreed upon adjustments required to stay on plan for the week. These daily adjustments are vital, as daily adjustments are easier than weekly adjustments, which are much easier than monthly adjustments and so on and so forth.

## 6. PREFABRICATION AND PARTIAL PREFABRICATION-

Prefabrication using large panel technology, allows relatively rapid construction of large numbers of buildings at moderate unit cost. The popularity of this method stems mainly from the cost savings provided by mass production of standardized building elements and the reduction of labour costs on-site. Prefabrication may be considered for whole buildings or for discrete components. For example, prefabricated components could include walls, floors, roofs, closet shelving/interiors or kitchen cupboards. It is important to note that additional costs may be incurred by the use of prefabrication methods. These may include the cost of shipping and handling, for example, particular care is needed when handling large concrete slabs. Extra reinforcement, care and precautions may be required to ensure the concrete slabs do not fracture or crack and joints are not stressed. The advantages of using prefabrication techniques in term of availability of materials, labour and technical skills are as follows-

Off-site manufacture of components with more efficient use of skilled labour, materials and specialized plant and equipment under controlled conditions offering components that are of a high standard.

- Accelerated erection on site.
- Market for new components resulting from envelope upgrades or spatial reconfiguration.
- Market in second hand components resulting from changes to dwellings or disposal of dwellings.
- Potential for relocation of dwellings rather than demolition.
- Minimal use of in-situ materials minimizes waste on site and at the end of the building's useful life. This reduces the manufacturer's liability for disposal.
- Self-supporting, shuttering and scaffolding is eliminated with a saving in shuttering cost, as the components are made ready.
- Mass production of building components results in increased productivity and savings per unit cost.
- Building components are factory-made, which avoid any adverse effects due to poor weather conditions.
- Possibility of implementing renewable energy devices in building façades as well as use of low cost sustainable materials.

Prefabrication is the production of housing or housing components using factory mechanization. The factory setting enhances affordability through a combination of bulk purchase of materials, mass production assembly techniques and the use of less skilled labour. Prefabrication can take one of three forms:

- PREFABRICATED COMPONENTS
- MODULAR HOUSING
- MANUFACTURED HOUSING

**7. LOW COST PREFABRICATION TECHNIQUES-**

(PARTIAL PREFABRICATION OF HOUSES)-

1) Prefabricated components-

Prefabrication of windows, doors, kitchen cabinets, and roof trusses has long had a place in home construction. Recent innovations have resulted in an even wider variety of prefabricated components, which increase affordability. The following are descriptions of some of these innovations and how they enhance affordability.

Walls and roofing There are many materials which may be used for the construction of walls. These include rammed earth, conventional bricks, soil cement blocks, hollow clay blocks, dense concrete blocks, and modular panels of various sizes. Although bricks are still the backbone of the building industry, large size panels made of low-density materials have increasingly been used for the construction of modular walls. The size of the panels depends on client requirements and the material used for construction. These materials include industrial wastes, such as blast furnace slag and fly ash, or a sustainable medium such as straw. This technology is economical in comparison with traditional brick wall construction due to greater speed of construction and lower mortar consumption. Prefabricated panels framed with wood or light-weight steel framing clad in a range of exterior and interior finishes can be used for exterior walls. The wall assembly usually contains insulation, wiring, and pre-cut openings for windows and doors. Costs are reduced as a result of a reduction in on-site labour.

A “panelised home” uses factory-made panels that include whole walls with windows, doors, wiring or outside siding. The components are brought to the site to be erected or assembled as required. Structural floors/roofs account for a substantial cost of most buildings. Therefore, any savings achieved in floor/roof construction considerably reduce the cost of the building. A traditional cast-in-situ concrete roof involves the use of temporary shuttering which adds to the cost of construction and time. Use of standardised and optimised roofing components where shuttering is avoided has been shown to be economical, fast and of higher quality. Some prefabricated roofing/flooring components found to be suitable in low-cost housing projects are precast RC planks, precast hollow concrete panels, precast RB panels, precast RB curved panels, precast concrete/ferrocement panels and precast RC channel units.

While the cost of a SIP house may be greater for materials, the shortened construction period and superior energy performance contribute to cost savings in both the short and long term. Roof panels, such as those made of Oriented Strand Board (OSB) have a short construction time and are uniformly sound and extra rigid to handle snow and wind loads. Roof panel systems can decrease the amount of labour required to roof a building by 30% to 40%.

**7.1. BENEFITS OF PRE-FABRICATED STRUCTURES-**

ECO-FRIENDLY-

Modular construction is often commended for energy efficiency and sustainable construction. Traditional construction methods require extra materials that lead to increased waste. However, since prefabricated sub-assemblies are constructed in a factory, extra materials can be recycled in-house. This is a considerable improvement over sending waste directly to a landfill from a traditional construction site.

FINANCIAL SAVINGS-

One of the greatest advantages of prefabricated construction would be financial savings. Although the perception of custom-made pieces may seem expensive, with prefabricated or modular construction, this is not the case. Modular construction targets all budgets and price points, creating an affordable option. Prefabrication manufacturers often receive bulk discounts from material suppliers which then trickles down to the cost of a construction project.

FLEXIBILITY-

Modular construction can be easily be disassembled and relocated to different sites. This significantly reduces the demand for raw materials, minimizes expended energy and decreases time overall.

CONSISTENT QUALITY-

Since prefabricated construction occurs in a controlled manufacturing environment and follows specified standards, the sub-assemblies of the structure will be built to a uniform quality. Construction site-built structures are dependent upon varying skill levels and the schedules of independent contractors. These all contribute to the craftsmanship and overall quality of given structure

SHORTER CONSTRUCTION TIME-

Portable construction takes significantly less time to build than on-site construction. In many instances, prefabrication takes less than half the time when compared to traditional construction. This is due to better upfront planning, elimination of on-site weather factors, subcontractor scheduling delays and quicker fabrication as multiple pieces can be constructed simultaneously.

SAFETY-

Since sub-assemblies are created in a factory-controlled environment utilizing dry materials, there is less risk for problems associated with moisture, environmental hazards and dirt. This ensures that those on the construction site, as well as a project's eventual tenants are less likely to be exposed to weather-related health risks. Also, an indoor construction environment presents considerably fewer risks for accidents and other liabilities.

## 8. LEAN TRAINING PROGRAMS-

**Employee Training**

Employee training is essential for an organization's success. Despite the importance of training, a trainer can encounter resistance from both employees and managers. Both groups may claim that training is taking them away from their work. However, a trainer can combat this by demonstrating that training is actually a crucial part of employees' and managers' work.

**Why Employee Training Is Important**

Training is crucial because it:

- Educates workers about the effective use of technology,
- Ensures competitive edge in the market,
- Promotes safety and health among employees,
- Creates opportunities for career development and personal growth, an important factor in retaining workers
- Helps employers comply with laws and regulations, *and*
- Improves productivity and profitability.

### 8.1. NEED OF TRAINING EMPLOYEES-

Every day some 950 people die and over 720,000 workers get hurt because of occupational accidents. Annually, over 48,000 workers die because of occupational accidents in India and there are almost 37 million occupational accidents which causes at least 4 days' absences from work. In terms of economics, the International Labour Organization (ILO) has estimated that the total costs of occupational accidents and work-related diseases are 4% of the gross national product (GNP). The total GNP of the world was approximately 75,592,941 million USD in 2013 (World Bank 2013) which means that worldwide the annual cost of work-related injuries and diseases is approximately 3,023,718 million USD. The construction sector is the second largest employer in India; however, accident statistics of the Indian construction sector are not properly and regularly published. Therefore, they are not easily available. However, it is expected that many fatal and non-fatal accidents would be happening in Indian construction due to its characteristics such as dynamic nature and involvement of many stakeholders including migrated labours in a project, and a less controlled environment.

### 8.2. KANBAN AND JIT TECHNIQUES AS LEAN PRINCIPLES-

Kanban is a scheduling system for lean manufacturing and just-in-time manufacturing (JIT). Taiichi Ohno, an industrial engineer at Toyota, developed Kanban to improve manufacturing efficiency. Kanban is one method to achieve JIT. The system takes its name from the cards that track production within a factory. For many in the automotive sector, Kanban is known as the "Toyota nameplate system" and as such the term is not used by some other automakers.

Kanban became an effective tool to support running a production system as a whole, and an excellent way to promote improvement. Problem areas are highlighted by measuring lead time and cycle time of the full process and process steps. One of the main benefits of Kanban is to establish an upper limit to work in process inventory to avoid over capacity.

A goal of the Kanban system is to limit the build-up of excess inventory at any point in production. Limits on the number of items waiting at supply points are established and then reduced as inefficiencies are identified and removed. Whenever a limit is exceeded, this points to an inefficiency that should be addressed.

**8.2.1. SIX WAYS KANBAN CAN BENEFIT TEAM'S PROJECT MANAGEMENT:**

**#1 Versatility**

.Because it's universally applicable, Kanban can be implemented by every team in your company from engineering to marketing to administration. Its versatility makes it simple for team members and projects to move seamlessly across functions.

**#2 Continuous Improvement**

One of the guiding principles of Kanban is that everyone should be focused on continuous improvement. Kanban's visual system of project management makes it easier to review processes and make improvements that cut waste, streamline workflow, and reduce overhead.

**#3 Responsiveness**

In project management applications, responsiveness is still one of the core benefits of Kanban. Using Kanban makes it possible to respond more agilely to business needs.

**#4 Increased Output**

Kanban encourages teams to limit how much work they have in progress at any time, a concept referred to as limiting "WIP" (work-in-process).

**#5 Empowered Teams**

The entire team owns the Kanban system and shares responsibility for moving work across the finish line. Kanban empowers teams to make more agile decisions that move projects forward with innovation and efficiency.

**#6 A More Perfect Product**

Kanban's focus on continuous improvement and agile responsiveness to issues often means that projects seen through to completion have fewer errors and require less rework. It puts quality control back into the project management process, yielding more accurate outcomes.

**9. LEAN CONSTRUCTION MATERIALS SUGGESTED-**

**1) FLYASH BRICKS**

Fly ash brick (FAB) is a building material, specifically masonry units, containing class C or class F fly ash and water. Compressed at 28 MPa (272 atm) and cured for 24 hours in a 66 °C steam bath, then toughened with an air entrainment agent, the bricks last for more than 100 freeze-thaw cycles. Owing to the high concentration of calcium oxide in class C fly ash, the brick is described as "self-cementing". The manufacturing method saves energy, reduces mercury pollution, and costs 20% less than traditional clay brick manufacturing.

| Material | Mass |
|---|---|
| Fly ash | 60% |
| Sand/Stone dust | 30 % |
| Ordinary Portland Cement/(Lime+Gypsum) | 10% |
| Total formula of material | 100% |

The strength of fly ash brick manufactured with the above compositions is ranges between 7.5 MPa and 10 MPa. Fly ash bricks are lighter and stronger than clay bricks.

1.1. Advantages outweigh the disadvantages of using Fly Ash Bricks over Clay Bricks.

Fly Ash Bricks Advantage:

1. Due to perfect size savings in cement mortar for making the walls and plastering by 20-40%
2. Strength of supplied lot is similar.
3. Plaster of Paris, Putty can be applied directly without a backing coat of plaster.
4. Lower water penetration to Clay Bricks.
5. High Strength-can be used for load bearing walls.
6. Eco friendly using Fly Ash.
7. 40% lighter than clay bricks

Clay Bricks Disadvantage:

1. Uneven shape
2. Labour Intensive.
3. Inefficient Kilns Coal Fired -Pollution
4. Cutting of agricultural land and hills -Pollution and against world food security.

Dimension of flyash brick = 23*11*7.5 cm
Dimension of clay brick = 19*9*9 cm

For a same area lesser number of flyash bricks are required hence the cost of construction is saved by 5 %.

Flyash brick has 24 % better compressive strength and 44% higher bond strength than the good quality clay brick. Also, the tensile strength of the flyash brick was three times greater than the value for standard clay bricks. The flyash bricks with conventional masonry work save 28% in cost compared with common red brick and conventional masonry work. The masonry work with new technology Rat-Trap bond in flyash brick saves 33% cost as compared to common bricks.

**2) RECYCLED PLASTIC BRICKS-**

Plastic is the biggest culprit when it comes to waste production; we throw away more plastic than any other material. Not only this, it also accounts for around 90% of all the waste that bobs around in our seas and oceans. The 3rd worrying factor is that it can take hundreds of years to biodegrade, making it a serious problem for future generations to deal with as well.

We can utilise such a waste material by transforming them into building material such as bricks which can be used for the construction of small structures like affordable houses for lower- and middle-income groups.

They also have several significant advantages over conventional bricks –

they're thinner and lighter, have superb heat insulating properties (5 times more than standard bricks) and are just as strong as their stony counterparts. They are also great at insulating against noise and it only takes 20 bottles on average to make one brick. Each brick helps rid the world of discarded plastic and is cheaper and more fuel efficient to manufacture than conventional bricks. It's also less energy intensive than recycling the plastic into other forms.

**3) GLASS FIBRE REINFORCED CONCRETE-**

Glass fibre-reinforced concrete consists of high-strength, alkali-resistant glass fibre embedded in a concrete matrix. In this form, both fibres and matrix retain their physical and chemical identities, while offering a synergistic combination of properties that cannot be achieved with either of the components acting alone. In general, fibers are the principal load-carrying members, while the surrounding matrix keeps them in the desired locations and orientation, acting as a load transfer medium between the fibers and protecting them from environmental damage. The fibers provide reinforcement for the matrix and other useful functions in fiber-reinforced composite materials. Glass fibers can be incorporated into a matrix either in continuous or discontinuous (chopped) lengths.The higher the zirconia content the better the resistance to alkali attack. The best fibers have zirconia contents of 19% or higher.

The design of glass-fibre-reinforced concrete panels uses a knowledge of its basic properties under tensile, compressive, bending and shear forces, coupled with estimates of behaviour under secondary loading effects such as creep, thermal response and moisture movement. There are a few differences between structural metal and fibre-reinforced composites. For example, metals in general exhibit yielding and plastic deformation, whereas most fibre-reinforced composites are elastic in their tensile stress-strain characteristics. However, the dissimilar nature of these materials provides mechanisms for high-energy absorption on a microscopic scale comparable to the yielding process. Depending on the type and severity of external loads, a composite laminate may exhibit gradual deterioration in properties but usually does not fail in a catastrophic manner. Mechanisms of damage development and growth in metal and composite structure are also quite different. Other important characteristics of many fibre-reinforced composites are their non-corroding behaviour, high damping capacity and low coefficients of thermal expansion.

Glass-fibre-reinforced concrete architectural panels have the general appearance of pre-cast concrete panels but differ in several significant ways. For example, the GFRC panels, on average, weigh substantially less than pre-cast concrete panels due to their reduced thickness. Their low weight decreases loads superimposed on the building's structural components making construction of the building frame more economical.

GFRC has become popular due to its numerous favourable properties:

- GFRC has been tested in the laboratory and also in the actual installations and can be anticipated to survive as long as pre-cast concrete. In numerous environmental conditions, like when exposed to salts or moisture, GFRC is likely to function better due to the absence of steel reinforcement that may corrode.
- Relatively light in weight compared to the traditional stones. Its installation is fast and comparatively simple.
- GFRC has the characteristics to be cast into almost any shape.
- GFRC consists of materials that are unlikely to burn. The concrete takes the role of a thermal regulator while exposed to fire and protects the materials from the flame heat.
- GFRC is thin and strong, with weight being 75% to 90% less compared to solid concrete. Less weight facilitates easy and rapid installation, and also decreases the load applied on the structure. The light weight and tough material also minimizes the transportation expenditures, permits flexibility in design, and reduces the impact on environment.
- Superior strength enhances the ability to endure seismic loads.
- GFRC is less vulnerable to weather effects and more resistant to freeze thaw than the normal concrete.

## 4) MOLADI HOUSING TECHNIQUE-

The Moladi building system involves the use of a unique removable, reusable, recyclable and lightweight plastic formwork mould which is filled with an aerated mortar to form the wall structure of a house in only one day. The process involves the assembly of a temporary plastic formwork mould of the size of the designed house with all the electrical services plumbing and steel reinforcing located within the wall structure which is then filled with a specially formulated mortar mix to form all the walls of the house simultaneously.

The Moladi formwork components are fully interlocking and are assembled into easy to handle panels, weighing only 8 kilograms per square metre, which are configured into a full scale mould of the desired structure. The formwork panels are joined to form the external and internal walls cavities, producing an ultimate wall thickness of 150mm for external walls and 100 mm for internal walls. All the steel reinforcing, window and door block-outs, conduits, pipes and other fittings are positioned within the wall cavity to be cast in-place when filled with the Moladi mortar mix. The Moladi mortar that is used to fill the wall cavity is essentially concrete without stone. The mix design of the mortar is specifically determined by laboratory tests that are carried out on local sand or aggregate, to ensure that quality standards are adhered to.

One generic cubic metre of Moladi mortar consists of-

1800kg of local decomposed granite / river sand
250kg of ordinary Portland cement: (OPC)
5 litres of [MoladiCHEM], a non-toxic,water based chemical cocktail
200 litres of water

After the wall cavities have been filled with the mortar, the mortar is left to set overnight and the formwork panels are removed the following morning to be re-erected on the next foundation. The wall has a smooth and flat finish that does not require any plastering, beam filling or chasing.

Its contribution towards skills development could play a vital role in that the application of the Moladi technology is not dependant on skilled labour or artisans in its construction method and utilises local unskilled and unemployed labourers to build Moladi housing units.This allows for greater community participation and as more than 90% of the construction team on a Moladi housing site consists of unskilled labourers, who are trained locally by a Moladi foreman over a period of 2-3 weeks in order to transfer the required skills and knowledge to complete the entire construction process. Moladi walls possess an average compressive strength of 15MPa or 15N/mm², which is far stronger than the average standard for cement blocks which vary from 3.6 N/mm² and 7N/mm² or common clay building bricks, which have a compressive strength of 5.2N/mm².

## 10. VALUE STREAM MAPPING-

**Value-stream mapping** is a lean-management method for analyzing the current state and designing a future state for the series of events that take a product or service from its beginning through to the customer with reduced lean wastes as compared to current map. A value stream focuses on areas of a firm that add value to a product or service, whereas a value chain refers to all of the activities within a company. At Toyota, it is known as "**material- and information-flow mapping**".

**Waste removal operations-**

1. **Non-value adding operations (NVA)**: actions that should be eliminated, such as waiting.
2. **Necessary but non-value adding (NNVA)**: actions that are wasteful but necessary under current operating procedures.
3. **Value-adding (VA)**: conversion of processing of raw materials via manual labour.

### 10.1. EIGHT TYPES OF WASTE IN THE CONSTRUCTION INDUSTRY-

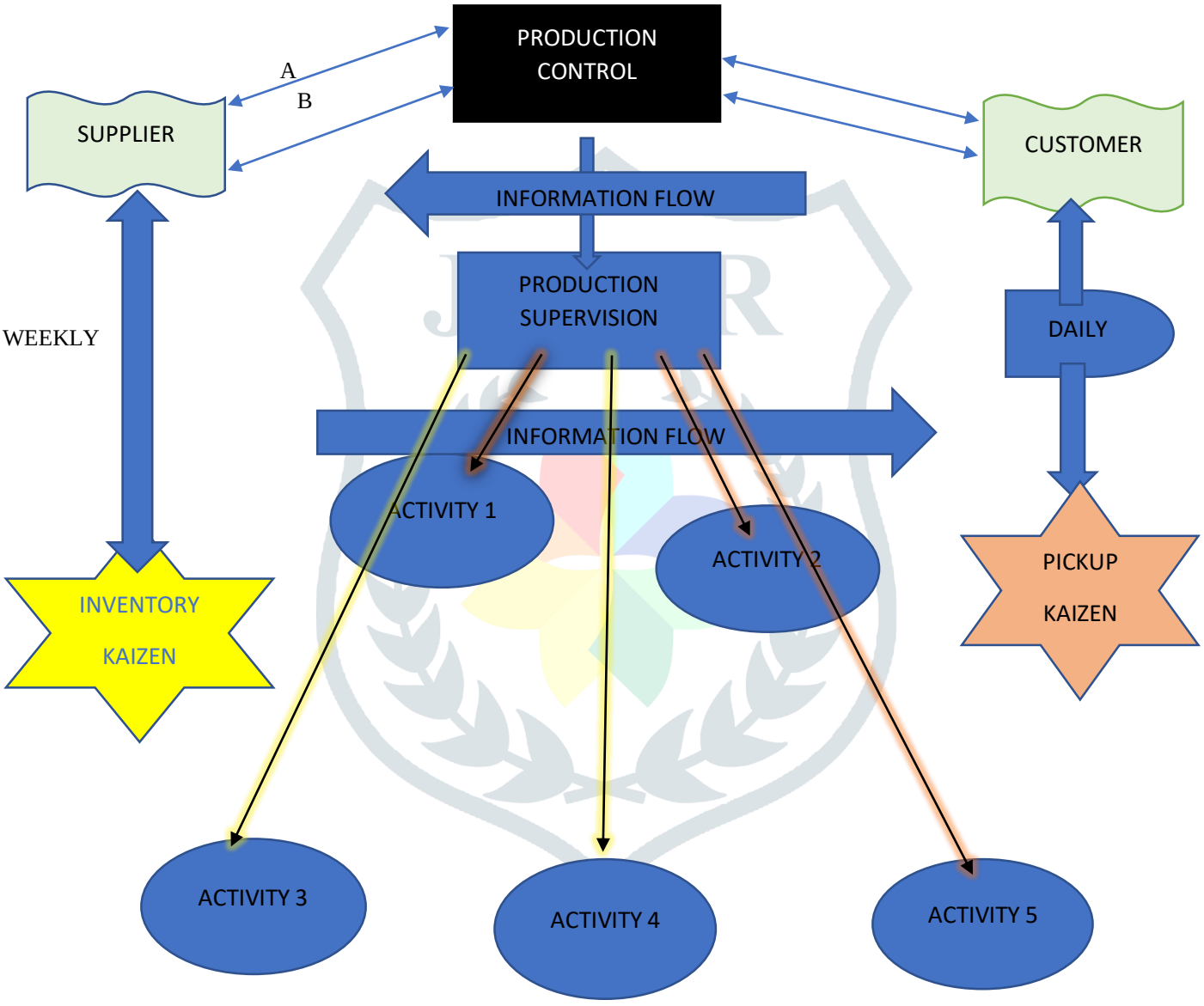
The following table list the 8 types of waste, typically found within the construction industry-

| Waste type | Definition/cause | Example |
|---|---|---|
| **Inventory** | Excess products and material not being processed. | Steel door frames delivered in bundles during steel erection. (Early delivering - just to be safe) |
| **Motion** | Unnecessary movements by people (e.g. walking). | Early delivery of the steel door frames got in the way of production operation and had to be moved. |
| **Defects** | Efforts caused by rework, scrap, and incorrect information. | In the process of moving the early delivered steel frame doors, some were damaged. |
| **Extra-Processing** | More work or higher quality than is required by the costumer. | Some of the damaged doors were repaired, and spending time ordering new doors. |
| **Non-Utilized Talent** | Under-utilizing people's talents, skills and knowledge. | Carpenters moved the steel frames to the construction install area. |
| **Transportation** | Unnecessary movements of products and materials. | New doors have to be delivered on site. |
| **Waiting** | Wasted time waiting for the next step in a | Waiting for the new doors to be delivered. |

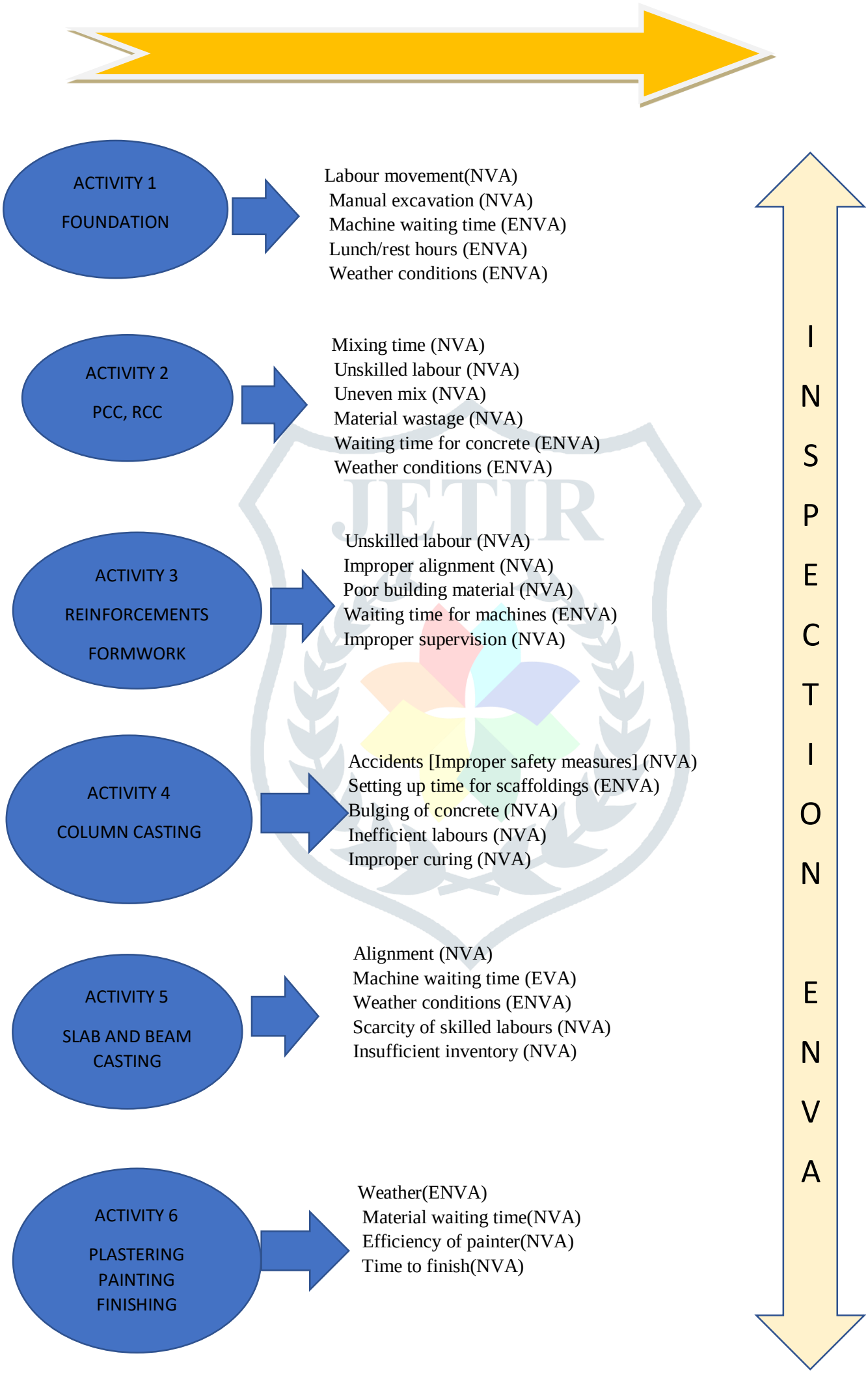
| | | |
|---|---|---|
| | process. | |
| **Overproduction** | Production that is more than needed or before it is needed. | Due to lack of doors to install, the carpenter began on other tasks too early. |

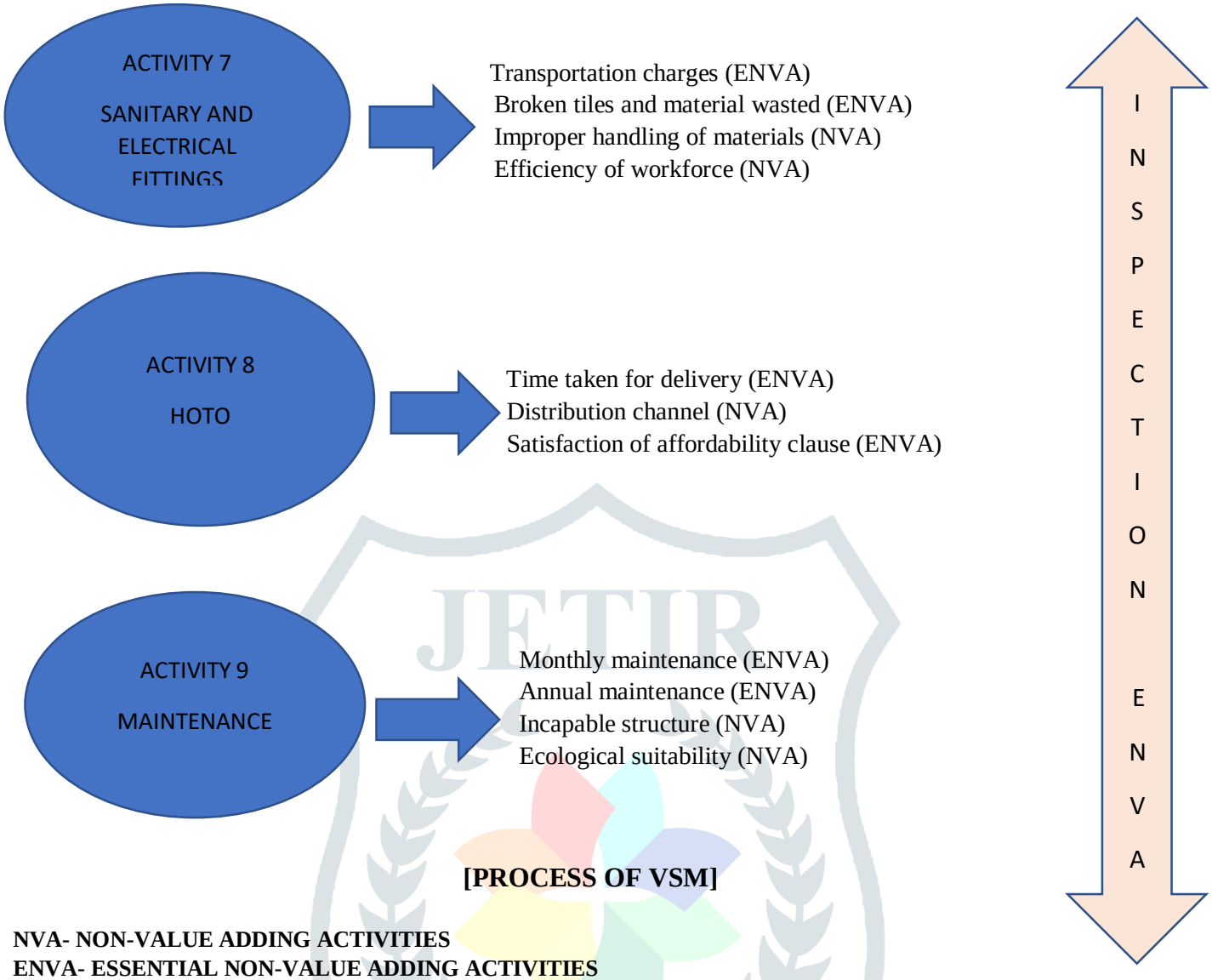
The basic objective of developing a VSM is to establish the flow of material, information and people; eliminate waste; and add value to the end product. VSM provides a systematic visual representation of processes, value added and non-value-added steps, lead times and inventories in the delivery of products (and projects). It provides holistic visual map of the production processes or supply chain network diffusing the implementation of lean concepts at the organization level.

VSM of the studied site construction-




**CALCULATION OF VA, NVA OF EACH ACTIVITY**


ACTIVITY 1
FOUNDATION
Labour movement(NVA)
Manual excavation (NVA)
Machine waiting time (ENVA)
Lunch/rest hours (ENVA)
Weather conditions (ENVA)
ACTIVITY 2
PCC, RCC
Mixing time (NVA)
Unskilled labour (NVA)
Uneven mix (NVA)
Material wastage (NVA)
Waiting time for concrete (ENVA)
Weather conditions (ENVA)
ACTIVITY 3
REINFORCEMENTS
FORMWORK
Unskilled labour (NVA)
Improper alignment (NVA)
Poor building material (NVA)
Waiting time for machines (ENVA)
Improper supervision (NVA)
ACTIVITY 4
COLUMN CASTING
Accidents [Improper safety measures] (NVA)
Setting up time for scaffoldings (ENVA)
Bulging of concrete (NVA)
Inefficient labours (NVA)
Improper curing (NVA)
ACTIVITY 5
SLAB AND BEAM
CASTING
Alignment (NVA)
Machine waiting time (EVA)
Weather conditions (ENVA)
Scarcity of skilled labours (NVA)
Insufficient inventory (NVA)
ACTIVITY 6
PLASTERING
PAINTING
FINISHING
Weather(ENVA)
Material waiting time(NVA)
Efficiency of painter(NVA)
Time to finish(NVA)
INSPECTION
ENVA




**[PROCESS OF VSM]**

**NVA- NON-VALUE ADDING ACTIVITIES**
**ENVA- ESSENTIAL NON-VALUE ADDING ACTIVITIES**

**TOTAL ESTIMATED WASTE TIME- 20-25% (waiting time, cycle time, transportation time, labour delays, manual works, machine break downs, unavailability of materials, weather conditions)**

**TOTAL ESTIMATED WASTED BUDGET- 10-15% (material waste, labour delays, transportation charges, cost of machines, over production, construction waste)**

**COST SAVING AFTER APPLYING VSM- 5-10%**
**COST SAVING AFTER IMPLEMENTING LEAN MATERIALS- 15-20%**

## 11. BARRIERS TO IMPLEMENTATION OF LEAN CONSTRUCTION TECHNIQUES IN AFFORDABLE HOUSING IN INDIA-

The main barriers to applying Lean principles in Construction industry in India have been identified as-

- Lack of exposure on the need to adopt lean construction
- Uncertainty in the supply chain
- The tendency to apply traditional management
- Culture & human attitudinal issues (Mindset issues)
- Lack of commitment from top management
- Non-participative management style for workforce.

**A. MANAGEMENT ISSUES**

This is probably the most critical issue and includes: delays in decision making, lack of client and supplier involvement and vision, lack of top management support and commitment, poor project definition, delays in material deliveries , lack of equipment, material scarcities, lack of time for innovation due to schedule and cost pressures, unsuitable organizational structure, weak administration, lack of supply chain integration and alliances, poor communication, use of substandard components, lack of steady work engagement, long implementation periods, inadequate pre-planning, poor procurement selection strategies, inadequate resources, embarking on large-scale Lean programmes at once (rushing), lack of customer focus and lack of long term planning due to contractual uncertainties are among the major managerial pitfalls for Lean.

**B. FINANCIAL ISSUES**

The implementation of innovative strategies like Lean Construction requires some funds. Adequate funding is needed to motivate the workforce, change processes, provide relevant equipment/material, train people and employ Lean specialists/consultants. Some of the financial barriers include project corruption, inadequate project funding, inflation, high initial implementation costs and lack of incentives and motivation.

**C. TRAINING ISSUES**

There have been several efforts to raise awareness, provide guidance and knowledge relating to Lean Construction by academics, researchers, practitioners and bodies such as Lean Construction Institute's (LCIs), Construction Lean Implementation Programme (CLIP), Construction Excellence (CE) and British Research Establishment (BRE). However, these bodies operate in very few countries. Despite the growing body of publications, training issues appear to be the most common pitfalls for Lean practices. This may be related to the fact that the concept was adopted from the manufacturing industry. Some of these barriers include conventional (old) construction management syllabi/teachings, lack of Lean understanding, lack of technical skills, high-level illiteracy, lack of training, not seeing Lean as a holistic system but a cocktail of techniques, inadequate knowledge, lack of project team skills, lack of Lean awareness programmes, difficulty in understanding concepts and lack of sharing and dissemination of the principles utilised.

**D. GOVERNMENTAL ISSUES**

Despite its significant economic contribution, the construction industry faces numerous government policy related problems. Some studies reveal that certain barriers arise due to government attitudes towards the construction industry in some countries. Those barriers include inconsistency in policies, lack of social amenities and infrastructure, materials unavailability and unsteady price commodities. Furthermore, some of the structural barriers like inflation and corruption could also be related to governmental issue.

**E. TECHNICAL ISSUES**

These barriers are considered technical because they have a direct impact on the implementation of certain Lean Construction techniques. Some of the major issues are lack of constructible designs, incomplete designs, poor performance measurement strategies (not process based), poor understanding of client's brief for value generation, lack of agreed Lean implementation methodology, lack of prefabrication, lack of standardization in the application of Lean techniques, overemphasizing quantitative benefits (not giving enough attention to the qualitative/non quantifiable gains), failing to demonstrate the business case for Lean, uncertainty in supply chain, lack of Lean systems thinking (implementing Lean ideas in partial "silos") and the fragmented nature of the industry as a barrier to teamwork and collaborative partnering.

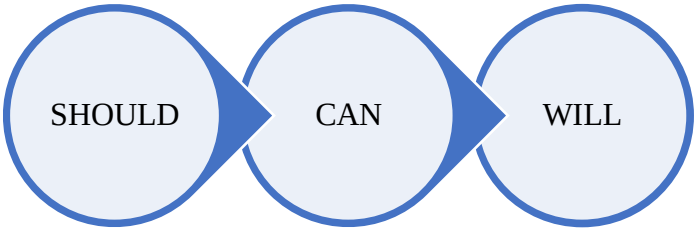
**F. HUMAN RELATED/ ORGANIZATIONAL ISSUES**

Some of these factors include lack of transparency, challenges in instituting a change culture, high personnel turnover, lack of self-criticism, lack of teamwork, lack of participative management/leadership, lack of cooperation and effort aligning (i.e. construction teams vs. commercial teams), rigid organizational structures/procedures, poor housekeeping, poor leadership, leadership conflict, not developing in-house Lean competency (too much trust on consultants/trainers), misconceptions about Lean Construction, over enthusiasm, seen as too complex and alien, seen as a management fad, seen as an exclusively manufacturing idea, seen as an exclusive business of the "Lean department", pseudo-Lean implementations for secondary reasons and fear of unfamiliar practices.

## 12. JUSTIFICATIONS OF THE STUDY-

### 12.1. TRADITIONAL VS LEAN (ON SITE)-

- Traditional methods of construction are irregular and step-by-step process is not properly defined and controlled as compared to lean methods of construction which work on the SHOULD-CAN-WILL approach with specific relevance given to controlling and execution.




- 
- Traditional construction techniques involve the use of year-old construction materials which have been utilised for years having greater carbon footprints and deteriorating the environment and also not beneficial to the structure whereas lean construction principles rely completely on clean and green technology which lowers the cost and time and also proves to be a healthier option considering the ecosystem. As for instance burnt clay bricks are substituted by plastic and flyash bricks and cement is substituted by flyash. The normal masonry structures are substituted by prefabricated structures which save 50% of time and hence prove to be more sustainable.

- Traditional methods of construction are simpler and hence the workforce required needs no training for the job. However, lean construction techniques involve technical skills and dedication to achieve the required output.

- Cost of construction reduces by applying lean construction techniques as follows-

  FLYASH BRICKS- Cost per brick = RS 2, red clay bricks= RS 3.5

  ( Flyash bricks are required less due to larger dimensions, they have smooth finishes hence cost of mortar and cementing is reduced, they do not absorb much water hence no deterioration, they do not need to be soaked in water prior to installation hence save time, they are environment friendly since flyash as a waste is consumed, they are self-cementing hence better compressive strength than clay bricks)

  ASHCRETE- consumes flyash as a waste and hence saves the environment, in producing 1 tonne of cement, 1 tonne of carbon dioxide is released, on a global level cement is responsible for 5-10 % of the total carbon dioxide emitted, this cement can be substituted by flyash in the industries which has almost the same chemical properties as that of cement hence both money and environment could be saved.

  MOLADI HOUSING- This technique uses plastic panels which are reusable for around 60-70 times to build structures instantly overnight without the need of curing using special mortar. It saves time, money and labous and delivers the product husslefree.

  PLASTIC BRICKS- Plastic as a waste is available in abundance and it takes more than 500 years for it to decompose since it is non bio-degradable. Such a waste could be utilised as a secondary material in manufacturing bricks and concrete and hence could be cost effective and environment friendly.

  VALUE STREAM MAPPING- Value stream mapping studies the current process and designs the future process with all those steps which are actually going to happen including all the value adding as well as non- value adding steps and then tries to streamline the process by removing all the non value adding activities which cause waste and delay. It is purely a management approach and a detailed study of the project is needed in order to save time and resources.

  LAST PLANNER SYSTEM- It involves making small plans and tasks for each day, week, month and finally leading to the master plan. It is a top-to-bottom approach where the entire plan is broken down into segments and each segment is inspected for PPP (Percentage plan complete). Daily reports are submitted to identify constraints and remove them, thus saving time and money.

  WASTE OPTIMISATION- Broken bricks and tiles can be used for landfilling and levelling the ground, steel and wood scrap could be recycled and used as substitutes in different forms hence saving money. It also prevents environmental degradation

- Lean production philosophy centers on the elimination of waste in all forms in the workplace. Specific lean methods include just-in-time inventory management, Kanban scheduling systems, 5S workplace organization, Scrum and other "agile" software development methodologies. Whereas traditional methods focus only on the delivery of products.

- Beyond simply reducing costs and improving efficiency, lean production techniques introduce systems and develop skills with your staff that support changes in the workplace that new sales create. Space saved on warehousing may be used to add new product lines. The same is true of time savings. The staff can absorb new work and react quickly to changes in client demand. Producing work quickly, in short iterations, without waste and delivered on time enhances your advantage over your competition.

- Lean method of construction focuses on the demands of the customers. It is a Demand- Pull system as compared to traditional method of construction which functions on the product- push technique by simply pushing the choices on the customers.

## 13. RESULTS AND DISCUSSIONS-

After studying the data from various sites, interviewing various builders from all over Lucknow and gathering ample amount of information from literature reviews and previous studies carried out on the implementation of lean construction techniques in affordable housing, I have reached to the following conclusions-

1) The mindsets of people including the builders, architects, masons, workers, developers, customers as well as the government is inclined towards traditional ways of construction as they find it more convenient to use what has been used for generations as it is easily available and not much efforts are needed in its implementation.

2) “PEOPLE ARE RELUCTANT TO CHANGE”- Change is something that a majority of people deny to imply. No matter how many technologies are introduced to the construction industry which can prove to be a game changer, if they are not implemented at the right time in the right way, they are of no use to the society. Efforts and consistency are what it takes to achieve what we dream of.

3) “INDIA IS A RICH COUNTRY OF POOR PEOPLE”- People do not want to spend money even for the persuasion of their basic needs i.e. home. In the name of Affordable Housing 80% of the private builders are constructing low cost houses using poor material and labour and selling it off at so- called ‘affordable rates’ and people are happily accepting to dwell in those units.

4) Lack of skilled workforce- Even if any lean construction material or technique in introduced to a construction firm it can not be implemented simply because the workforce lacks a basic skill to work with these techniques. Training of labours, masons and other workmen is something that needs to be taken very seriously.

5) Governmental policies and guidelines- Construction of houses in India is not considered a very tedious job. As a matter of fact, any person who has enough resources to buy a piece of land and construct dwelling units becomes a builder. Thereafter he can easily get clearances from the government and build houses which can later be sold out. There are no such policies in the Indian Government which decide the type, size, location, materials and kind of structure that qualifies the basic building norms.

6) Safety in Construction- Construction work in India lacks the basic safety measures. As per statistical reports of the government, more than 48,000 workers die every year and more than 1,20,000 a
Get injured because of the lack of proper safety measures on the construction sites. This causes a loss of life, property, time, mental disturbance, lack of work satisfaction and a disruption in work.

7) Population and needs- Home is the basis of survival of people. With the increasing population in India and the increasing need of houses, especially for the middle- and low-income segments of people, it becomes almost impossible to dedicate much time and efforts to the field of effective construction. India still lacks 19 million units of houses, which, if not intervened by rapid development and housing schemes by the government will grow to 30 million by 2030.

8) “GREED IS BIGGER THAN NEED”- It may sound impractical and theoretical, but the bitter truth of the society is that it is Greedy. The money allocated by the government for building Affordable houses goes through various channels, gets divided, after which it reaches the builder. This money is not enough for building a proper house with well defined architecture. Hence at some point even the builder compromises the quality of the product for seeking his own profits. This is the plight of construction industry in India and we are still calling it a “*DEVELOPING COUNTRY*” does it deserve that label?

## 14. CONCLUSION-

This study is an initiative to develop a better thought process among people including all the stakeholders from the builder to the labour, the architect as well as the house owner about the utilisation of all those processes which will bring about a change in the environmental conditions, the resource buffers, sustainability conditions as well as aesthetics and finances of the country. The idea is to eradicate the deep rooted cultures of the Indian society in context of the utility of resources, the processes involved and implementation of construction practices which have been performed by our forefathers since ages and are continuing to deplete the natural resources and the environment as well.

Carbon footprints can almost be eradicated by utilising these techniques and materials of construction. We just need to widen our approaches and mindset to step into this new era of innovation and revival. Some of the suggested methods and techniques would be-

- Last Planner System (LPS)
- Value Stream Mapping (VSM)
- Waste Minimisation and reutilisation.
- Reverse Phase Scheduling (RPS)
- Percent Plan Complete for every day scheduling and removal of constraints.
- Daily Hurdle Meetings to keep the stakeholders involved in the project.
- Work Breakdown Structure (WBS) to identify each element of the project.
- Just in Time technique (JIT) to avoid overproduction.
- Utilisation of alternative construction materials to safeguard the environment.
- Energy efficient designing foe saving resources.
- Involvement of top management for qualitative deliveries.
- Improvising labour skills and inspection on site.
- Questionnaire surveys to the top builders of UP for better understanding.

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