

CONSTRUCTION 4.0: THE 4th GENERATION REVOLUTION

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ABSTRACT

Global economy has evolved from Agriculture to Industrial to Services and now to Digital. In digital economy, technology is the key driving force by optimizing human interventions throughout the lifecycle of the product. Technology also provides exceptional experience to digital age customers, employees and other stakeholders. India has a major focus on Construction in terms of investments in housing (more than 60 millions till 2022) and infrastructure in coming years. It is imperative now to best leverage technology for improving effectiveness, efficiency, labour productivity, quality and most importantly stakeholders' happiness.

For this, 4th Generation Construction revolution has started. Technologies like SMAC (Social media, Mobility, Analytics, Cloud), Artificial Intelligence, Augmented & Virtual Reality, 3D printing, Internet of Things/ Sensors etc.) are playing vital role in this revolution. Technology today also enables exceptional collaboration, coordination and communication in 'Real Time' among various construction stakeholders.

Using the recent concepts of Lean Digital Thinking™ and Construction 4.0, developed by VSR (Refer Acknowledgement), author highlight show Construction Industry landscape will change. These 4th Generation changes will improve Construction performance manifolds, in complete Lifecycle, starting from Design, Pre-construction to Construction Execution. This is the time to prepare India for 4th Revolution through Lean Philosophy & DIGITAL Technologies. Two Indian cases are outlined in paper, where some of these concepts have started giving fantastic results.

KEYWORDS

Lean Construction, Lean Digital Thinking, SMAC, IOT, Construction Technologies, Construction Life Cycle Management

EMERGENCE OF 4th GENERATION CONSTRUCTION REVOLUTION

Global economy has evolved significantly over last century. The earlier economic growth was driven by Agriculture, and then from early 20th century to mid seventies economy was driven by manufacturing all kind of products to make life better. Later, the growth was driven by Service economy, like Logistics, IT services etc. Now it is driven globally by disruptive digital technologies (SMAC, IOT, 3-D Printing and many other propriety emerging technologies). Digital India, Digital USA, Digital Germany are common words for countries now, reflecting this. The products, services, processes, including in Construction Industry, are getting digital and disrupting all organizations for the new-age tech-savvy Gen. Y and Gen. Z (Randstad, 2014) customers & other stakeholders. Figure 1 depicts this, visually.

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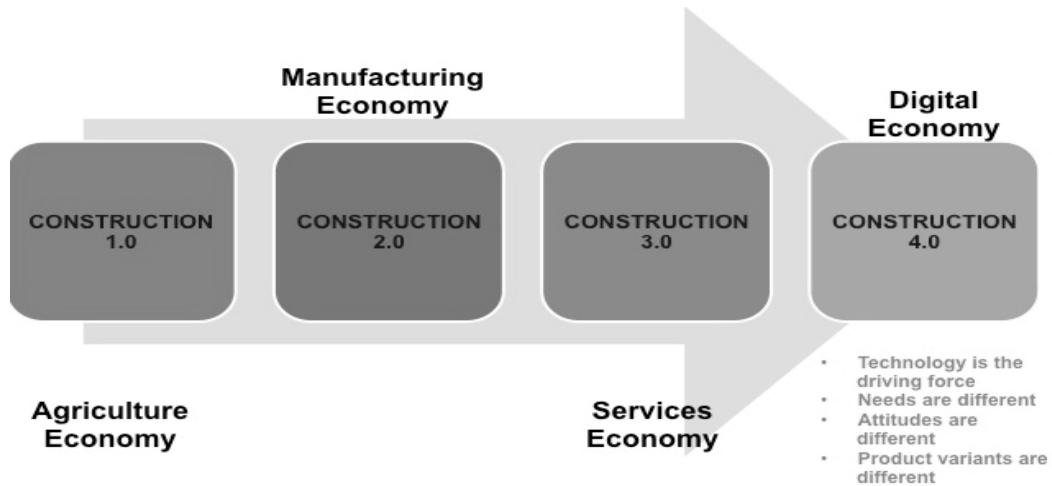


Figure 1: Evolution of Construction 4.0

Construction Industry has also effected by this and has evolved during last century, moving from one generation to another, in terms of processes, practices, technologies, capabilities and value (e.g. Rastogi 2015). Evolution can broadly be stated as:

- **Construction 1.0:**predominantly labour oriented, with not many specialized disciplines as are very common presently.
- **Construction 2.0:**Mid 20th century saw many specialized disciplines (e.g. Architects, Project Management), some automation through Construction Equipments, but site work was still largely labour-oriented. Also adopted soft wares like ERP, Project Management software. But still resultant productivities are very low with cost and time over-runs.
- **Construction 3.0:** Late 20th Century saw technology driven Architecture &Design (like, BIM), Lean processes & systems, further automation of Construction Activities & more softwares like CRM, Enterprise-wide Project management etc.
- **Construction 4.0:** In 21st century, specially during last 8-10 years, four major changes have occurred and are growing exponentially:
 - Technology is the driving force. SMAC, Big data (including unstructured data like text, voice, image& video data), Artificial Intelligence, Virtual& Augmented Realty, 3D printing, Internet of Things/ Sensors etc. started playing vital role in this revolution, as these became cheap and affordable.
 - Needs & attitudes of End Users changed drastically: Gen Y and Gen Z, are extremely tech-savvy, impatient, educated, globally-connected and uncompromising, demanding world-class quality at frugal rates, expecting very memorable personal experience during house purchase & possession.
 - Construction focus is also shifting to mass-customization at agile speed especially in the urban areas, on one hand; and mass-production at very high speed of at rural area (for both housing and other infrastructure).
 - There is special stress on sustainability and green construction, due to changing climatic conditions in the globe, which was low priority in past.

Most countries including India, currently are at best working at Construction 3.0 level. However, now there is a urgent need to jump to Construction 4.0, because of challenges of

construction industry. This new generation of Construction 4.0 poses its own challenges, at the same time offering new innovative solutions.

CHALLENGES IN CONSTRUCTION 4.0, FOR INDIA

The investment in Construction Industry is estimated globally at fabulous 10.3 Trillions USD by 2022, contributing to 13% of the global GDP. In India it is proportionately even more, at 1.8 Trillions USD by 2022. This scenario is very different than the past, and specially for the new 50% customers belonging to Gen Y and Gen Z categories, India being very young country for the next few years. Due to high demand and low construction productivity, the key issues in India are:

- Big demand for investment, but shortage of Capital
- Very high demand of housing (> 60 millions in 5 years)
- Several new Government initiatives, like 100 SMART Cities, SMART water & Power grid, Infrastructure for Make in India, Digital India etc.
- Changed expectations of biggest customer segment (the Youth)
- Mass-customization in Urban housing & mass-production in rural housing
- 100% FDI allowed in Real Estate, bringing many MNCs in India, looking for Indian Partners, who can work with world-class practices & technologies
- Real Estate regulation & development Bills, with several restrictions and severe penalty clauses for delays and poor quality
- Very poor productivity and profitability, at present
- Increased Complexities, due to demand for greater novelty & technology
- Shortage of skilled labour and also management skills
- Increasing focus on sustainability
- Big overhead of regulatory constraints (> 75 approval required in India)
- Impractical planning, inefficient project construction & business processes
- Very high amount of rework and wasteful construction & business activities
- Low collaboration, communication and coordination among contractors

Because of all these, if Indian Construction practices don't transform, it can't achieve the goals it has set for 2022. In fact, McKinsey Capital Projects & Infrastructure (2017), in its global research report mentions that if the Construction productivity could catch-up with the productivity of the total economy, the industry's value added could rise by USD 1.6 Trillions a year, globally. This alone will meet world's annual infrastructure needs or boost global GDP by 2%. Similar conclusions can be drawn for India, although no such research is available here. A framework is developed for India to best leverage technology for improving effectiveness, efficiency, labour productivity, quality and most importantly stakeholders' happiness significantly. This is described below.

THE FRAMEWORK TO MEET CHALLENGES OF CONSTRUCTION 4.0:

Technology fusion and Lean Digital Thinking drive this framework, as explained in next paragraphs.

Technology Fusion

Leveraging fusion of various technologies can provide manifold improvement in the productivity and profitability of construction industry covering entire lifecycle of the project. The technologies are classified in three categories as shown in figure 2.

Workflow Automation Technologies (WT): These cover various software like ERP, CRM, eCommerce, Portals, Project Management, AutoCad, BIM 3D, 4D & 5D etc. These manipulate and handle Structured data like numbers.

Communication & Collaboration Technology (CT): These cover Virtual Reality (for customizable Mock-up walk-through), Augmented Reality (for very informative & interactive eBrochures), eCommerce (for buying/ selling/ renting/ comparing properties), SMAC (for collaboration, communication and coordination among various stakeholders, anywhere, anytime using any devices), Big data (analytics of Text, Voice, Images and Videos for understanding customers behaviours more accurately and for better expectations management) etc. WT technologies are now available on Cloud, minimizing CAPEX need of the companies. All these technologies are capable of handling unstructured data like Text, Voice, Images & Videos etc.

Operational Technologies (OT): These include various Sensors (like, Motion, Thermal, Vibrations, Noise, Length Measurement, RFID etc.), Many emerging Construction Technologies like Pre-fabrication, Pre-cast, Metallic/ Plastic or Hybrid formwork, Automation of concreting, plastering, 3-D Printing, Robotic Block or Tiles laying etc. All these can handle both structured and semi-structured data.

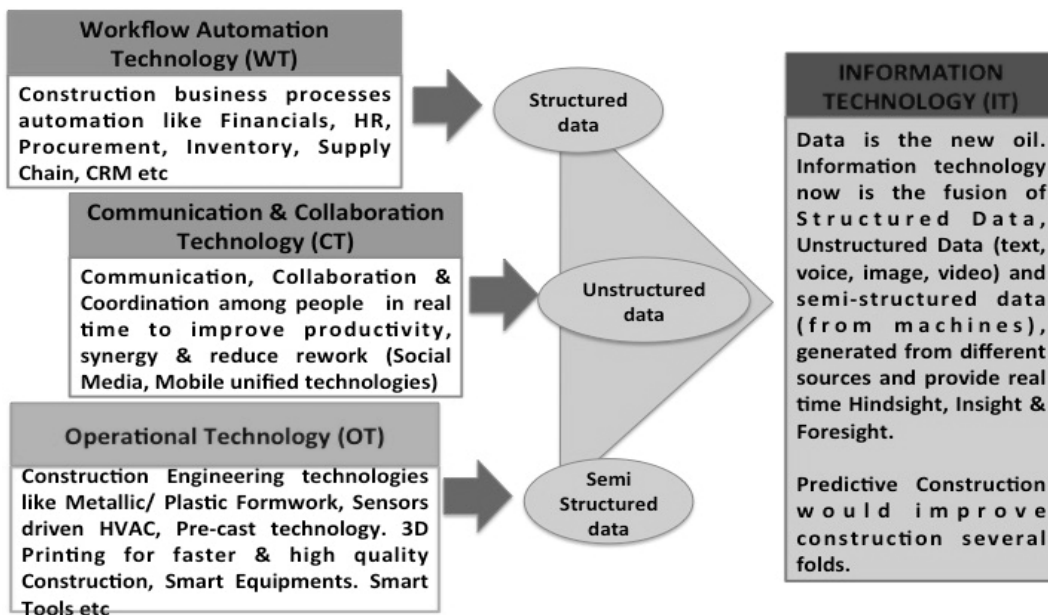


Figure 2: Fusion of Technology

Fusion of these technologies results in Digital or new Information Technology, and leveraging this fusion in Construction Industry innovatively has tremendous scope for enhancing productivity and profitability improvements manifold.

Lean Digital Thinking™: The Twelve Principles

Lean Digital Thinking is another driving force to prepare for Construction 4.0 challenges. These 12 Principles (similar to Toyota’s 14 principles but contextualized for fusion of technologies era) will change the Construction Industry globally.

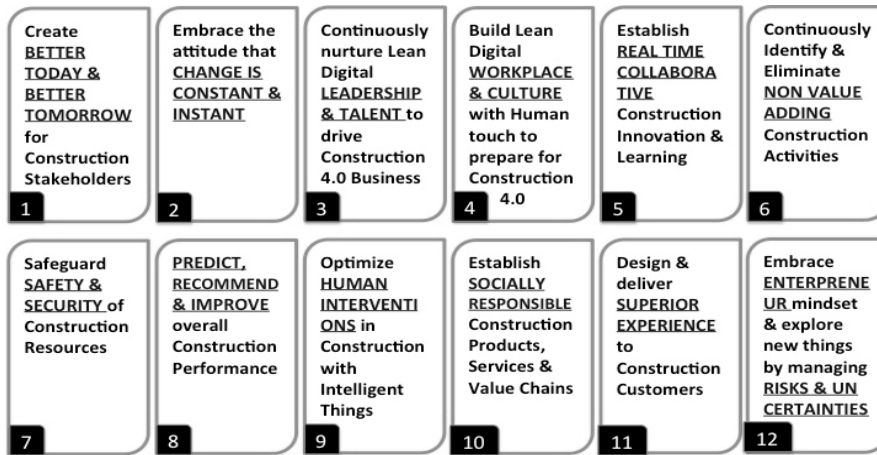


Figure 3: Lean Digital Thinking: 12 Principles

Brief explanation of each principle, mentioned in figure 3, is given below.

LDT Principle 1: Embrace the current & future trends, resolve current & unmet future need to excel in today's business and work to realize future aspirations to survive & excel in next few years become 'future-proof' and 'future ready'.

LDT Principle 2: People are highly connected & collaborative and expect response instantaneously. Sensor based Intelligent things should optimize human interventions and enabling agile operations and instantaneous change.

LDT Principle 3: Leadership team and workforce must learn and practice Lean Digital skills, processes, practices, behaviors etc., to excel in digital economy.

LDT Principle 4: New rituals, values, policies, language, symbols need to be introduced to nurture Lean Digital culture to succeed in digital economy.

LDT Principle 5: Digital World reduces the physical barrier of distance and removes the communication barricades. Digital Workplaces leverage real time communication, collaborative software platform helping to learn, innovate & execute collaboratively.

LDT Principle 6: Identify & Eliminate Wastes in digital economy. Besides the eight wastes of Lean also identify digital wastes like Excessive Data and Irrelevant Insight, Unnecessary Smart Things/ Devices& sensors, Over Collaboration & Conversations.

LDT Principle 7: In digitally real-time connected economy, people, assets and businesses will encounter many Cyber Security, Safety and Privacy issues. Hence take care of preventive and corrective cyber security, safety & privacy practices.

LDT Principle 8: Since high volume & high variety of data is generated at high velocity. Data handling without Algorithms is useless. Enterprises must intelligently leverage right insight using Descriptive & Predictive and Prescriptive Analytics and auto recommendation (without expert) by leveraging algorithms.

LDT Principle 9: In Digital economy, People and Things (like Robots) work like TEAM and many human interventions in business operations would be optimized.

LDT Principle 10: Products, Services and value chains designed by leveraging Digital Technologies must always be socially responsible.

LDT Principle 11: People have different needs, expectations and aspirations. Selling "Unforgettable Moments of Experience" along with products and services is very essential. Experience design is must to acquire life long customer.

LDT Principle 12: Digital Businesses require Agility, Speed and Explorative work environment rather Stability & Predictability. This needs entrepreneur mindset.

In Construction 4.0, Technology Fusion and Lean Digital Thinking impact the eight pillars of construction as mentioned in Figure 4 below. Hence construction organizations have to assess and improve each pillar very carefully.



Figure 4: Eight Pillars of Excellence in Construction 4.0

In this paper, author provides two case studies, covering Pre-construction and Core construction (quality & project management) which have leveraged Construction 4.0 framework in different degree. These mini-cases will also give idea how this framework can be a game changer for Construction Industry in India.

CASE 1: PRE-CONSTRUCTION PHASE (DESIGN)

In most design & build projects, Client is often not very clear about its Dream, Aims and Objectives about the project, mainly due to lack of visualization. This often leads to several iterations of designs, discussions and arguments among the Clients, Designers & Architects and the Build teams. There are regular changes in the requirements, finishes, with many iterations along the project, leading to potential budget & delivery date enhancements. There are rework, delays, escalated costs, and dissatisfaction for quality. In short, the unclear dream of client leads to most of these problems.

Newer technologies like Virtual Reality, Big Data, Analytics, Cloud and others, can resolve many of these problems and eliminate lots of wastes associated with several iterations and associated project delays, poor quality, customer dis-satisfaction and budget-spill-overs. Lean Digital Thinking helps in creating a new culture & attitude among stakeholders to best leverage the lean & digital practices. Below is a real-life case completed recently, which explains briefly, how Virtual-Reality-Aided-Build addressed this problem amicably. Project focussed on five of the eight Pillars of Excellence (refer fig. 4), namely interactive virtual reality supported Product Design, better & interactive Customer Services, digital technology supported Design & Execution processes, belief in Lean Digital Culture and Tools & Equipments and achieved unparalleled success. Project used fusion of technologies like 2D AutoCAD, 3D Modelling Tools 3DS Max and Maya, Game Engine software stacks like Unity, Unreal etc to create Virtual Reality, Social Media (WhatsApp), Mobility, Analytics. This finally resulted in measurable benefits like minimizing the number of design changes and removing the clashes of pipes etc. in MEP & Civil drawings during execution. Client also got the real feel of his dream & unforgettable experience early about the final product (Refer Table 1). The investment in this subscription-based software was negligibly low, although it required a technical gaming expert.

Project Name : Virtual Reality Aided Build: for premier MNC Consulting company.
Project Size : Workplace Design & Build, 23,000 Sq Ft carpet area in Bengaluru
Project Cost : In the range of about INR 3.7-4.0 crores

Leveraging of Lean Digital Thinking

In this project, besides using several LDT Principles 1, 4, 6, 7, 10 special focus was given on LDT Principles 2, 5 and 11, as explained below.

LDT Principle 2: All changes based on the interactive feedback of clients were incorporated almost instantaneously due to integration of AutoCad, BIM & VR.

LDT Principle 5: Strong collaboration among Client, AutoCad team, BIM Team and VR developers was established successfully. Also high level of collaboration and communication was created among the Client, Design-Build team, Leadership Team, along with the Architects for interactive feedback.

LDT Principle 11: Developed detailed design and Virtual Reality mock-up, based on clients’ key stakeholders’ inputs and have them walk-through it to provide them "Unforgettable Experiencing the office before it was ready"the re-designed environment after taking final feedback before starting actual detailed designs.

Table 1: Benefits achieved to Customer & Design-Build Consultant in the project

Performance	Benefits	Remarks
Customer Satisfaction Score	100%	Client had clarity on its dream beforehand, which was converted into reality. Client’s feedback some minor change were almost incorporated instantaneously. Excellent Teams Alignment. Interactions using Social Media
Design+ Build Delivery (# of Days)	> 35 %	Reduced total delivery time from estimated 90 days to 70 days despite accommodating some last minute changes
Quality of work	20 % improvements	Early identification of potential snags resulted 20% reduction in Snags (in comparison to similar projects done in past based on non-VR technologies). This was despite making some last minute changes. Also resulted over 15% reductions in (estimated) Drawings Changes during execution.
Budget/ Cost	Reduced > 10 %	No unexpected cost escalations, which was common earlier projects. No escalation of Material Cost/ BoQ change, Very low rework Cost, by preventing Snags and minimizing drawings changes.
Health, Safety & Environment	Zero Accident	Advance knowledge of potential safety hazards helped in managing this better



Figure 5: Virtual Realty Picture versus Actual Picture

CASE 2: CONSTRUCTION PHASE (EXECUTION)

In a far off place like Panvel in Maharashtra, a 3BHK Villa of 1700 Sq. Ft Carpet area was to be built on a marshy riverside land plot. In traditional way of construction, it would have taken 210 days, from Architecture/ Design to handover, along with many quality issues, rework and increased last minute additional costs. However, new ISB educated new entrepreneur tried new ways & focussed on six of the eight Pillars of Excellence of Construction 4.0 (refer fig. 4). With focus on 100 standard Product Designs, better & interactive Customer Services, across-the-table Design & Execution processes, belief in Lean Digital Culture, internal Talent development, and using better Tools & Equipments, they were able to achieve phenomenal success. They took advantage of Technology fusion, specially Operational Technologies like Pre-fab of Columns, Beams, Slabs, Slant Roof; AAC blocks, and Communication & Collaboration Technologies like Social Media, Mobility and Analytics. This required a total investment of less than one crore of Indian Rupees, in building internal machines for various automation, and buying some 100 Designs. Total business of about 1.5 Lakhs sq. ft. will break even this investment. Following some principles of Lean Digital Thinking (refer fig. 3), the project was completed in just 105 days in stead of normal average of 210 days, a saving of 50% in delivery time and saving more than 5% in final cost of the project (refer Table 2). Below are some more details:

Project Name : Dighandhar Villa
Project Size : 3 BHK Villa, 1700 Sq Ft carpet area,
Project Cost : 43 Lakhs Indian Rupees

Leveraging of Lean Digital Thinking

Besides using Lean Digital Principles like Principles 1, 3, 7, 10, special focus was given on LDT Principles 5, 6, 11 and 12 as explained below.

LDT Principle 5: Used collaborative planning and agreed on schedule (figure 6). Used extensive level of collaboration and communication among Owner, Builder and Designer periodically, also when required. Used Social Media (WhatsApp) extensively to share pictures of work progress & key materials finishes, documents, messages and teleconferencing. Also used a simple home grown Mobile App for Quality Process Controls (specially filling checklists on mobile at site)

LDT Principle 6: Eliminated most of the wastes at site, by minimizing site activities, and doing most of the activities off-site at factory. (Plz see fig 6 and 7 for details). Some of important operational technologies / design used were:

- a. Pre-Cast Columns, Beams, Slabs and Inclined Roofs in factory in Gujarat. Transported 3 truck-loads of pre-fab materials from Gujarat to 300 kilometers away site.

- b. Used AAC Blocks for all walls for faster laying and better insulation
- c. Used only thin Gypsum plastering for great finish for painting
- d. Used Piles Foundation due to loose earth at site

LDT Principle 11: Discussed with Customer along with a library of 100+ (and still growing) of pre-designed Floor Plans and Structural Designs. These helped Client to choose and partially modify to customize to his requirements. This reduced design time by more than 50% and created very accurate BoQ, based on past data on computers. This also provided great experience of getting the finished product exactly as was agreed by client and he had picture in mind right from day 1.

LDT Principle 12: Embraced Entrepreneurial mindset for exploring many new things like Prefab at factory, despite it being 300 KM away from the site, needing 3 truckloads of Pre-fab material to be transported, still reducing overall cost (ref Fig 8)

Table 2: Benefits achieved to Customer & Builder in the project

Performance	Benefits	Remarks
Customer Satisfaction Score	100%	Dream house was realized completely; Made only one visit to site before handover
Design+ Build Delivery	50%	Reduced from 210 days to 105days
Quality of work	Excellent	Zero Snags identified by customer
Budget/ Cost	Reduced > 5%	Owner saved Finance Cost (3.5 months Rent of old flat); Better Cash Flow, lower Finance Cost, No rework or escalation Cost, Very limited site work (refer fig 8)
Environment	Clean	Very limited excavation required and low material / water & power wastage at site

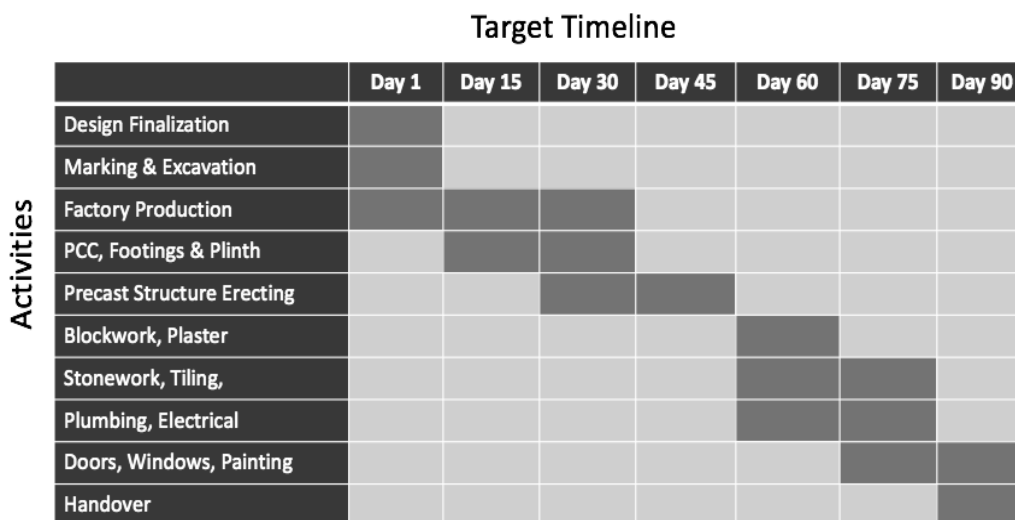


Figure 6: Collaborative Agreed Schedule

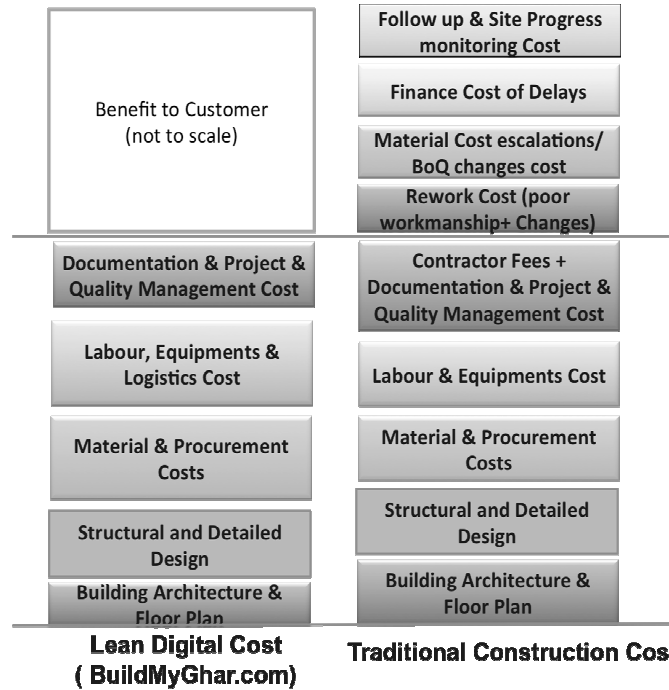


Figure 7: Traditional vs. Lean D Cost



Figure 8: Villa under construction



Figure 9: Finished Villa

CONCLUSIONS

In conclusions, the author would like to emphasize that looking to the huge challenges of new demand in Infrastructure and real Estate of the country, availability of limited Capital, expectations of new Gen Y & Gen X clients and also entrepreneurs, current low productivities& profitability etc., entry of several MNCs and FDI, low skills of worker etc. there is strong need for a 4th generation revolution in Construction Industry. This revolution should leverage the Construction 4.0 framework, leveraging the Fusion of various technologies (Workflow, Communication & Collaboration and Operational), along with the Lean Digital Thinking to meet the new expectations of developed India. The benefits of such changes are visible from the initial use of this framework in the two case-studies mentioned here.

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