WORKING PAPER on 'DESIGN PROCESSES'

Ci3 *India* - Action Team 3A – 10 Oct. 2016

1 Introduction

1.1 Background

Efficiency and effectiveness of design process contributes significantly to performance of a building construction project. During the initial stages of a project, the influence of design decision is high, whereas the cost incurred in implementation is low. There are no standards specifying the building design process in India. Hence there are no benchmarks based on which activities in the initial project phases can be planned and monitored. This results in an adverse impact on the downstream phases. In this study, design process data from different organizations developing building projects were collected and analysed. The analysis revealed that there was significant variability in design durations due to organizational priorities. However, there were no documented standards or benchmarks on the appropriate design duration for various types of projects. In order to develop such benchmarks, it is proposed to standardize milestones and durations associated with the design process. The preliminary work done towards developing a design management standard is reported in this paper. This includes the development of standard design workflows and phase durations based on project type. It is anticipated that the availability of a standard will enable better planning and implementation of the design phase.

1.2 Need for Action

The design process involves identification of customer requirements and their translation into design specifications (Ballard, 1998). Efficient management of design is necessary to control issues stemming from the complex nature of the design process. These issues include poor communication, inadequate technical knowledge of designers (Ballard, 1998), deficient planning, omissions and errorneous information and design changes (Sverlinger, 1996). Further, poor management of the design process can render the constructability of the design questionable, affecting the performance of the execution team (Ballard, 1998). Modern construction projects are complex in nature and aspire speedy completion of design. These put additional pressure on designers who need to consider multiple options during the conceptual stage of design. Futher, common design tools support developing only single static solutions and there is a lack of formal methodology for generating multiple design options (Gane et. al., 2010).

Construction projects are subjected to variation in the manner in which the design phase is executed across various organizations. This variation can be attributed to the unique cost, time and scope associated with a project. This variability reflects the absence of benchmark and standards which render the planning and monitoring of the design process difficult.

1.3 ***Objectives & scope***

The objective of the work is to study a cross-section of current typical design processes in India and suggest improvements and best practices to manage them better. Initially, the design processes of some typical leading client organisations are mapped and the different methodologies adopted for design management are studied. Contractual strategies and organizational priorities are studied and compared to evaluate the variability in terms of timescales and methodologies. The specific causes that give rise to these variabilities are identified and discussed.

1.4 ***Impact of Recent Regulations on the Design Processes in India***

Failure by building clients in adhering to initial designs have resulted in huge end user dissatisfactions and the consequent Real Estate Regulatory Act of 2016, which prevents sale of projects until the completion and registration of design details. The offset of the commencement of cash inflow due to RERA is, therefore, largely dependent, if not proportional, on the duration of early planning and design stages of the project. Figure 1 is a graphical representation of the impact of RERA on the construction project delivery. The shaded part of the graph indicates the excessive financial overburden on the project, induced by the Act.

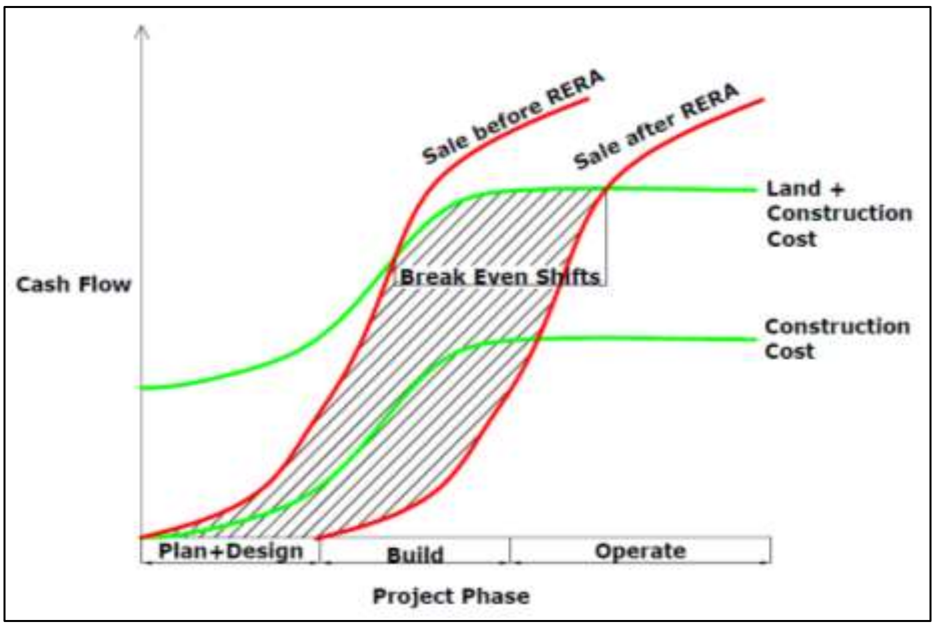

Figure 1: Impact of RERA on Project Cash Flow

2 Methodology

As a first step, participants of Action Team 3 were invited to a workshop on 29th April 2016, in order to understand from clientele themselves, all the issues faced by construction industry in the design management context, irrespective of their importance. The outcome of this was a comprehensive list of issues in construction design (Ci3 India, Design Process Preliminary Report, 2016). Of the plethora of design related issues, the identification of specific key issues required a more detailed study, which has been performed subsequently.

Figure 2 illustrates a generic swim lane diagram for design processes, with the different teams and their activities represented as horizontal bands along the different design stages. Such swim lane diagrams were developed for four participating organizations visited, to map the design processes associated with specific types of building projects. These diagrams were then analysed to understand critical issues in the process. Discussions were held to identify best practices, specific issues encountered and timelines in the stages of the design process.

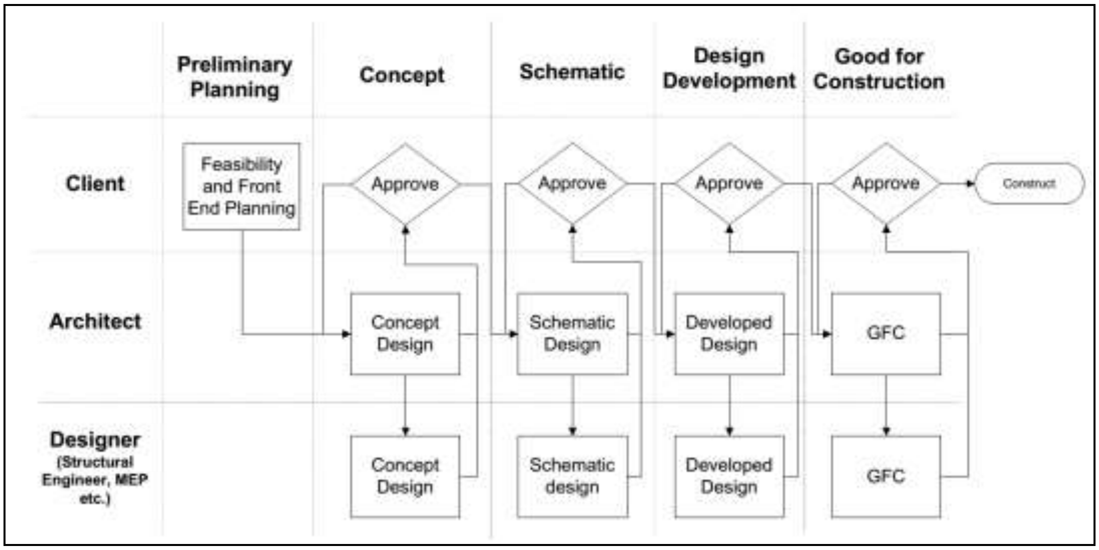

Figure 2: Generic Swim Lane for Design Processes

Subsequent to data analysis, suggestions put forth are presented to the Action Team 3 members at the Review Meeting held on 30th August 2016. The suggestions recommended are then modified to incorporate comments from both design developers and users.

3 Findings Outcomes and Discussions

3.1 Findings from Literature review

Several studies have identified the influence of design management on overall success of a project. These studies have revealed major issues such as poor planning and management, ineffective communication, uncertainities, variations and project complexity. To overcome these issues and for the application of design management tools and techniques we need to develop a systematic framework to improve the design management process.

Design process in construction suffer from poor planning and management (Koskella, et. al., 2002). Ineffective communication governing design process leads to errors and omissions in design (Williams, et. al., 2013). Uncertainties in design arise from technological changes, market trends and time and cost constraints (Ballard et. al., 2009). Design process are subjected to variation in time, cost, scope and design construction interface (Anderson, et. al., 2005). Most of the research till date has been focussing on improving design from a designer's perspective. The inability to incorporate organizational and project specific issues have further aggravated the situation (Tzortzopoulos et. al., 2007).

The construction industry is found to be deficient in developing a systematic scheme to improve design management practices (Tzortzopoulos et. al., 2007). Lack of conceptual base is the major reason for the poor level of design management. Application of tools and techniques for design improvement call for development of appropriate framework of design process as well for design management. This can be achieved through standardization of the design management process for the development of models or protocols for design which could be specific to a company or the entire construction industry (Formoso et. al., 1998). Design Management tools can inturn aid in the efficient design management and effective use of available resources (Chhabra et. al, 2011).

Design Management in India can be characterized by the lack of standardized plan of work and hence the inability to provide the necessary framework for the activities in the various project phases. The RIBA plan of work in UK, for example, provides a framework for building design and construction process through the entire lifecycle of the project.

Through the development of standards, failures attributed to errors and omissions in design can be reduced (Williams, et. al., 2013). Standards should be explicitly based on current best practices, providing enough scope for innovation.

3.2 Findings from Data Collected in India

Organization	Type of Organization	Type of Projects	Operating cities	Design Focus	Strategy for achieving objective
1	Real Estate developer	Residential, Commercial, Hospitality	Bengaluru, Mysore, Chennai	Timely design and project delivery	Compress design stages and fast track
2	IT firm	IT offices	Hyderabad, Bengaluru, Kolkata	Operational efficiency	Include climate consultants from concept design
3	Real Estate and Infrastructure	Mixed use	Mumbai, Gurgaon, Chennai	Overall focus on Return on investment	Evaluate multiple concept options based on changing market trends
4	Real Estate developer and redevelopment	Mixed use and redevelopment	Mumbai, Pune, Bengaluru	Stage wise design focus on Return on Investment	Check budget complaince after each design stage

Table 1: Key attributes of Organizations visited

The key attributes of each of the organizations are presented in the Table 1 above.

The specific swim lanes mapped for each of the organizations are attached as Appendix A, Appendix B, Appendix C and Appendix D.

Based on the discussions with experts and analysis of the diagrams, the following inferences are drawn:

1. **Design is priority-driven**
   The duration of design process is largely dependent on the priority of the organization.
2. **Variability in the concept design duration**
   Variability adds uncertainty to the process which brings in unpredictability. Figure 3 graphically represents the comparison of stage duration (derived as mean value of the range). As inferred from the chart, among the 5 stages in design, the maximum variation in duration between the 3 organizations is found to be in the concept stage.

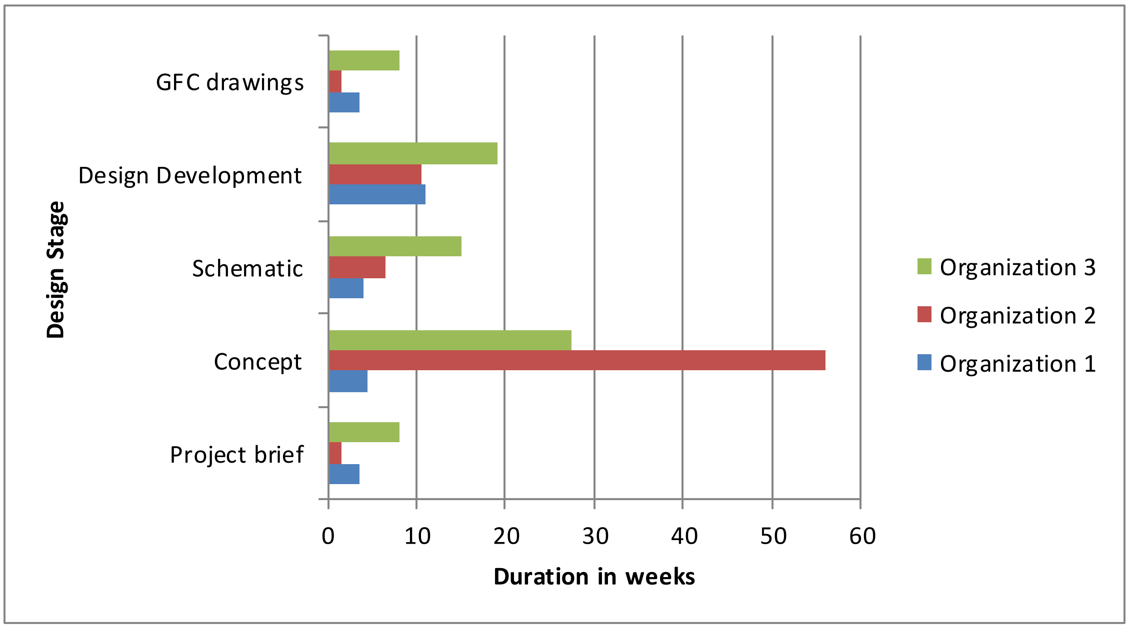

Figure 3: Graphical Comparison of the duration of design stages

3. **Art causes variability in design duration -** The time taken for aesthetics in conceptual design introduces significant variability.
4. **Time lost in conceptualizing unapproved designs** – Time taken by architects to develop alternatives that do not get approved are not adding direct value to the project.
5. **Evidence of procedural design in the downstream design stages -** It can further be observed from Figure 3 that irrespective of the type of organization/project, the downstream design stage durations are less variable, indicating the availability of standards resulting in more uniform durations.

From the inferences drawn, the proposal for standardizing design processes was developed and presented to the forum of clients. The forum found standardization of design process and timelines to be the need of the hour. However, such standardization shall constrain the creativity of the designer.

General worth of design may be augmented by clientele asking for design with higher weightage for science in design. Therefore, by bringing out standard design schemes/templates, more impetus shall be on the effectiveness of design. But such standards will have to be made based on classifications of the targeted customer pools.

In the proposal put forth, clients are to influence the architects to pre-develop a *library* (market) of standard concept design templates to delink the time taken to ideate the concept, within the timeframe of project delivery. This could help clients choose from a set of readymade concept options for the project and then refine it to suit their project. This can further give clientele a larger set of conceptual alternatives to choose from.

To validate this suggestion, practicing architects were interviewed and they opined that building design always revolves around a central theme of art, which is the most important aspect of concept design. The components of concept design that cannot be delinked from the central theme are spatial organization, circulation, ergonomics, anthropometry, energy optimization etc. Therefore the *library* will need to sell readymade concept design sets as packages with a certain level functional development. The proposal is valid in the sense that a project has to now be designed in modules (or smaller sets) that are assembled to form the concept of the entire building.

4 Way forward

The study shall be extended toward developing benchmark timelines and standard design process charts across the different building verticals. In the subsequent stages, the development of standard design templates need to be developed with the help of standard bye laws for India. Strategies like the library of concept designs can be experimented to detach the uncertainties in design process, notwithstanding art/creativity in design being given enough room that at no stage does building design cease to evolve.

The team needs to also develop a strategy to implement and evaluate collaborative planning as a comparison with the developed standards to ascertain the benefits.

5 Conclusion

The following conclusions are made from the study:

1. The priorities of an organization largely influence early design decision stages.

2. The highest degree of duration uncertainty is presently in the conceptual stage.

3. There is a need for standardization of design process in the Indian context

4. There is a need for collaborative planning

6 References

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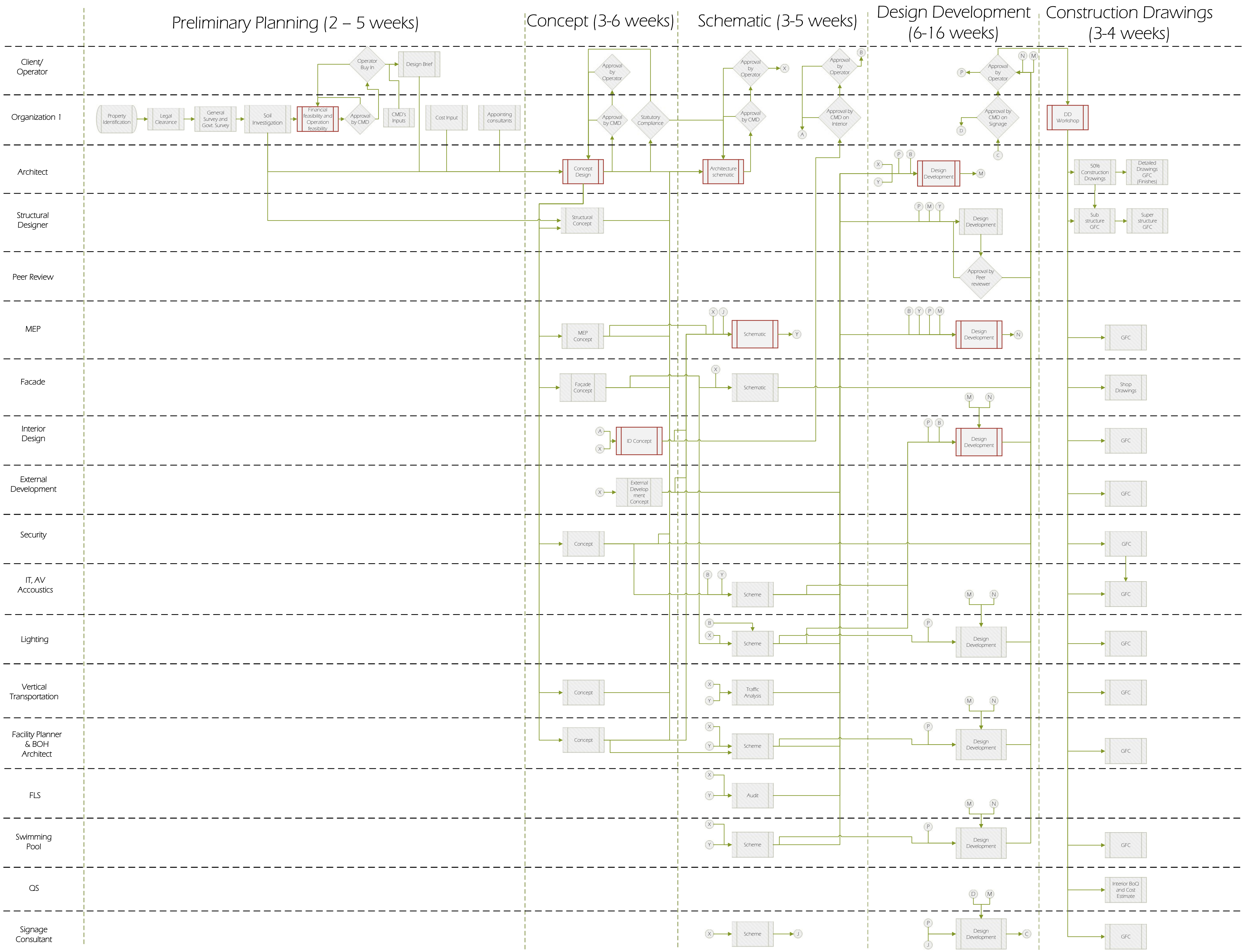
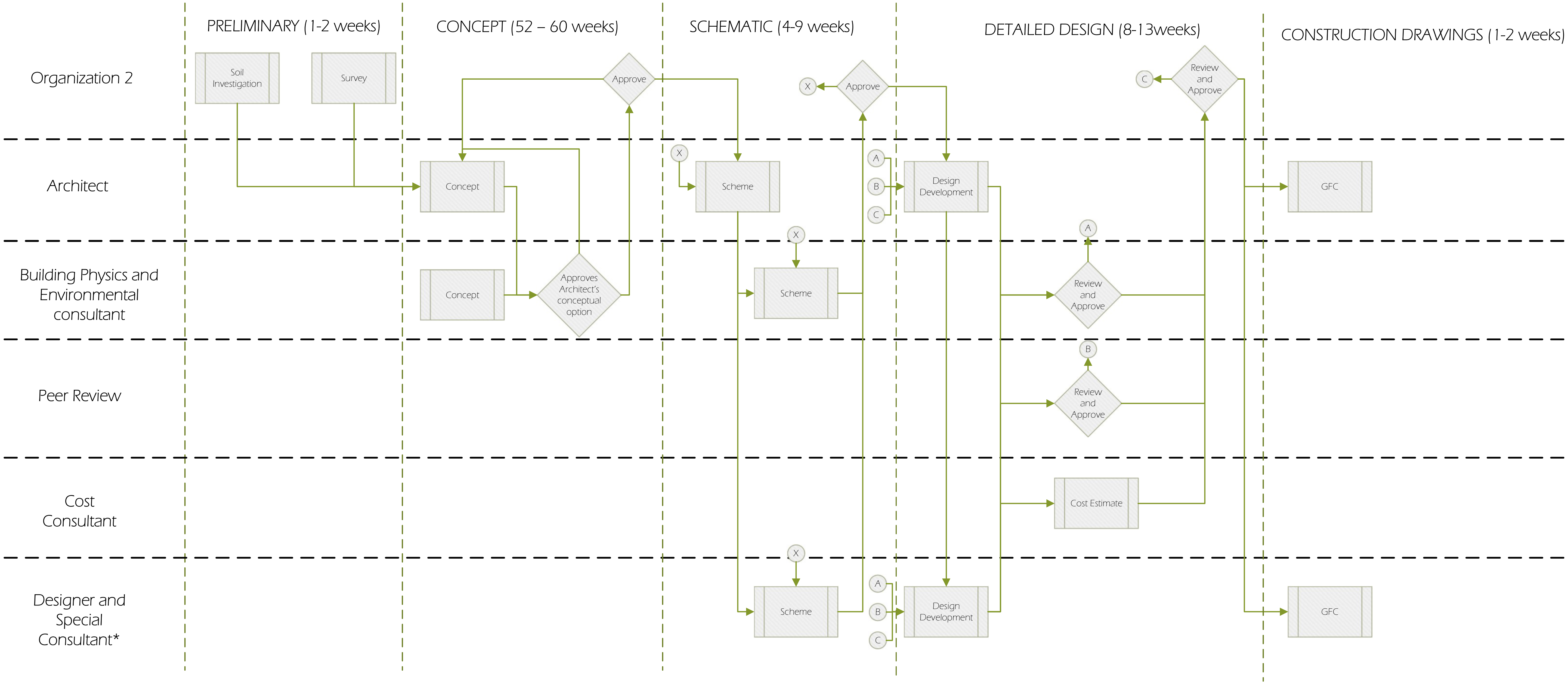
Appendix A - Design Process for Hotels (Organization1)



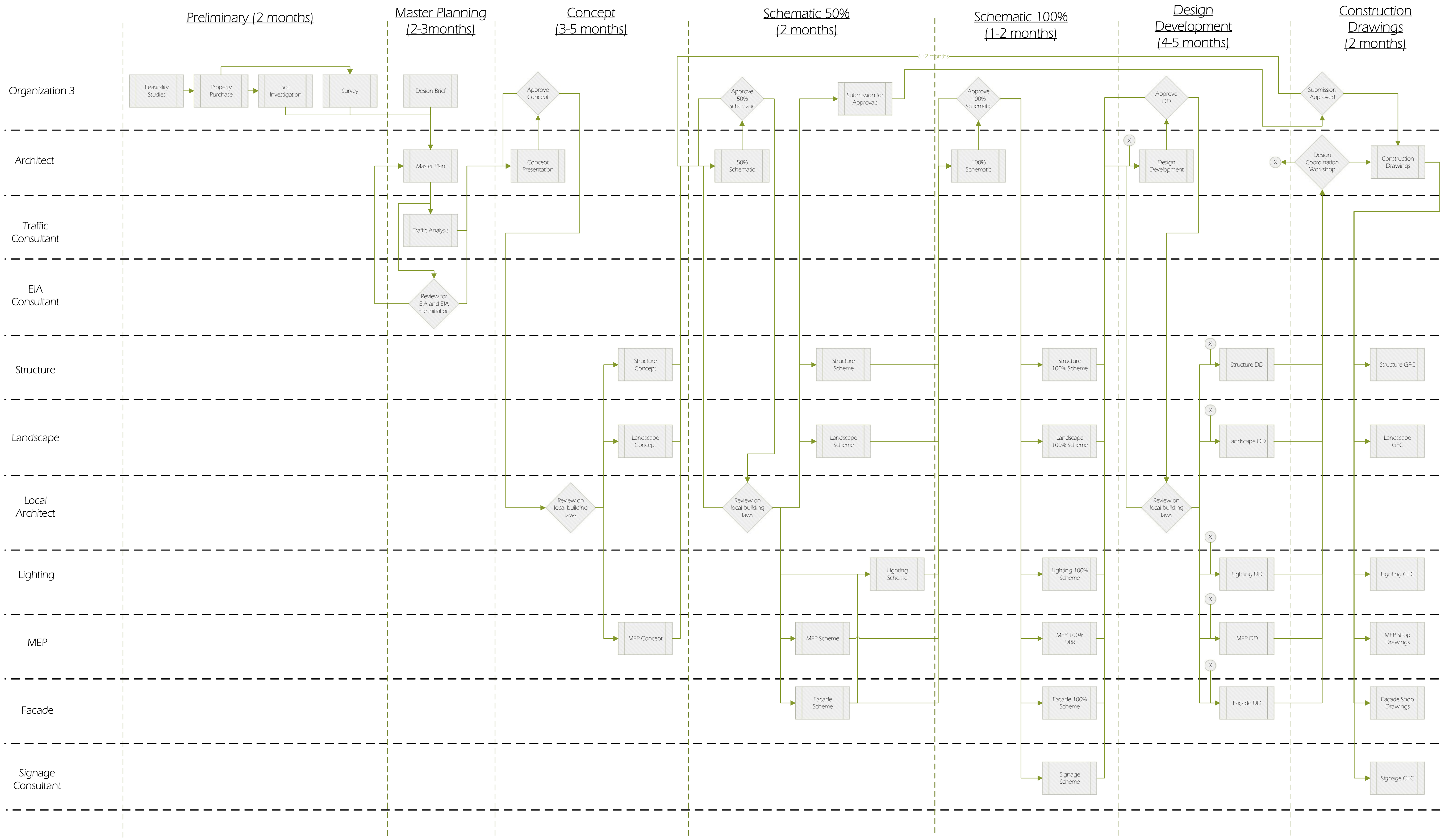
Note: As Built drawings, developed after the construction stage mark the end of Design Stage

Appendix B - Design Process Chart – Organization 2

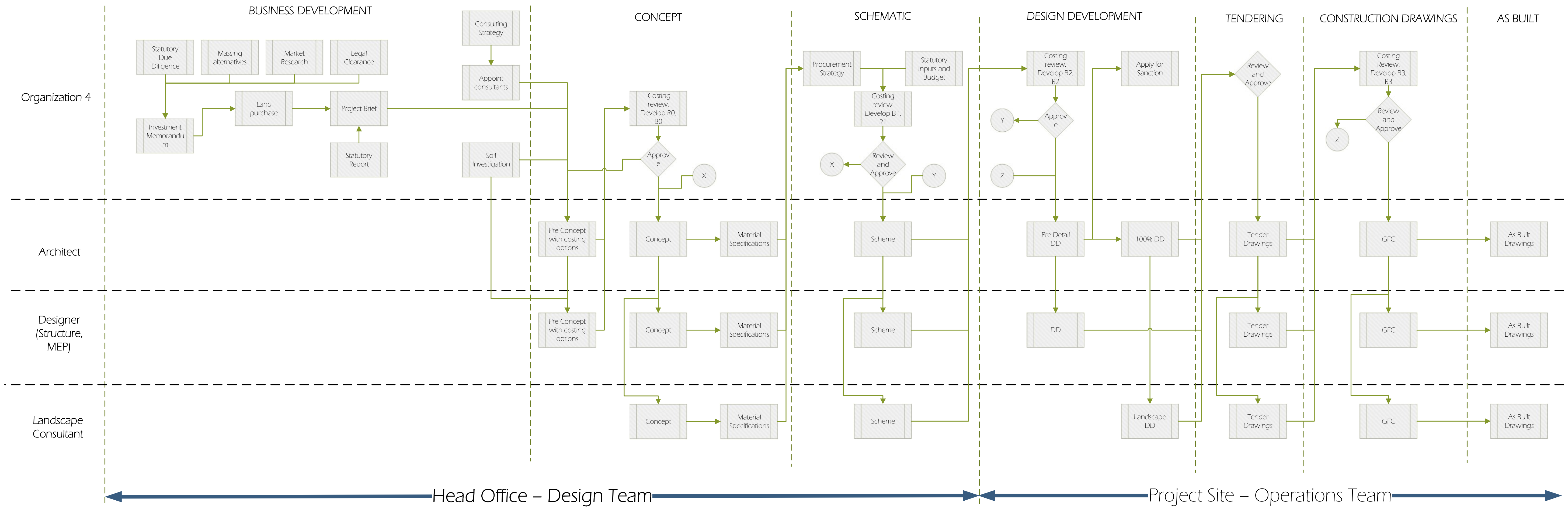


*Special Consultant includes Façade, Landscape, Vertical Transportation, IT, F&B

Appendix C - Design Process Chart – Organization 3



Appendix D - Design Process Chart – Organization 4



Working paper on ‘Technology Adoption in Construction’

Ci3 *India* - Action Team 3B

1. INTRODUCTION

1.1 Background and Need for “Action”

The construction industry has generally been a late adopter of technologies that can improve project productivity. On the technology adoption curve, construction tends to be in the lower 50% of the adopters. In fact, productivity studies on the role of IT in improving productivity identified construction as the last of the 15 verticals to adopt technology and mechanization for improving productivity.

There are inherent characteristics of the industry that are identified as reasons for delayed adoption of technology. One of the most significant one is the fragmented nature of the industry which in turns leads to its disconnected processes and sometimes unstructured work environment etc. In this environment, it is not clear who benefits from the productivity improvement and that is probably a significant factor that hinders technology adoption. In fact, to be fair, there is an increasing move towards mechanization and there has been a growing trend in adopting some technology solutions. And a cursory look indicates that when productivity improvement is for one particular stakeholder in the construction project, it tends to get adopted. In short, does not depend on technology factors only but also on people and processes. It has been found that most technology adoption efforts fail, if people, processes & policies are not in place to support the technology platform. And this is particularly true for information technologies.

1.2 Principal Concepts Underpinning the Action Objectives

Notwithstanding the above environment, industry and academic fora has in general felt that the industry should take a more proactive stance on adopting and getting the benefits of technology. And these benefits can be realized by the projects (and the industry) if Owners as client demand their usage in order to overcome the initial barriers to technology adoption. In the context of Ci3 itself, it is also recognized that the outcome of the other action items will also influence this action item. For example, better management of time and cost can be achieved through better adoption of technology and mechanization. Some of the KPIs that Owners are looking to measure to measure project and process performance can be better enabled by some of the information technologies available today etc.

Buildings today have evolved from relatively simple products with a primary focus on structural requirements to complex products with multiple systems and multiple performance (often contradicting) requirements to be delivered on a compressed schedule. In order to effectively manage projects in this increasingly inter-related and complex nature of projects involves the need for information technologies that help manage projects from concept to commissioning, automation through equipment technology, and a coming together of all the stakeholders sharing information in one central platform.

Finally, emerging nations such as India face several additional issues in the adoption of technology which need to be recognized and addressed.

1.3 Objectives & Scope

The above are the primary drivers and purpose behind the formation of this action item. Based on the above, the objectives of this action item are:

- Discuss and understand the drivers of technology adoption process in the Indian construction industry.
- Identify issues and barriers in the current technology adoption process and the root causes for the same
- Develop strategies for improving the technology adoption process in order to meet project delivery requirements of today and tomorrow as outlined by other action items

2. METHODOLOGY

As part of the work done till date, a concept note was circulated to the Ci3 participants. Team members and experts were invited to a workshop to discuss the technology adoption issues on the 29th April, 2016 at IITM, Chennai. During the workshop, participants discussed both equipment technology and information technology related issues. The summary of discussions at the workshop are summarised as follows:

- Information Technology
  - Organizations use technologies only at the basic level and they do not tap the full potential of the technology (example: Microsoft Project or Oracle Primavera is used only as a dashboard tool to represent activities and not used as a full-fledged planning solution)
  - There is a lack of awareness about the technology options available today for users to understand its full potential. And for this to happen there is a need to focus more on training
  - There is a need to link the different business processes carried by different stakeholders (from engineering to construction) in the projects for better technology adoption
  - For a collaborative adoption and use of technologies, all the key stakeholders should be interested in effectively adopting the technology
  - Owners should start contractually implementing technologies in their projects. Owners should also get involved with appropriate use and monitoring of the technologies adopted in order to derive benefits of the technology
  - All the stakeholders need to jointly identify the ROI parameters to justify the use of technology
  - Interoperability among existing technology solutions should be devised to drive integrated project management practices and identifying methods and means to drive BIM based processes and technology into the industry
- Equipment technology
  - Organizations need to clearly calculate ROI to evaluate the choice of equipment technology and justify the choice and the investments of equipment technology
  - There is a lack of skilled and quality operators and man power to handle new equipment and there should be a focus on training
  - The owners should develop awareness of the available technologies during the design phase itself so that they can better mechanize the execution activities, plan for the same, and reduce wastage during execution
  - Owners should also develop a detailed specification on the equipment to be used along with the BOQ and implement it contractually
  - Impact of manpower shortage in Indian construction sites today can be offset through effective use of equipment technology and the automation that it brings; that alone could be the justification for Owners to adopt automation and technology
  - Robotics technology needs to be explored and enhanced usage has to be done particularly for working in dangerous zones and risky areas

Table 1 below outlines the issues identified in the adoption of equipment and information technologies.

Table 1: Issues in adoption of Technology

Equipment Technology	**Information Technology**
• Cost of Technology • Lack of awareness • Return on Investment • Cost – Productivity (vs conventional) • Training Facilities • Local Maintenance Requirements • Local Repair Service availability • Limited Scope of repeated usage • Suitability for local conditions • Flexibility for varied requirements • Import regulations	• Cost of Technology • Lack of Awareness • Lack of ROI Models / Low ROI • Who pays Owner or Contractor • Data Security Cloud/On-location • Interoperability • Data Availability • Training • Local Support for customization • Lack of Specialists (IT Construction) • Organization structure (BIM Coordinator?)

• Local Transport • Low Tech Culture • Limited Rental options • Contractual Requirements	• Low Process maturity for IT adoption • Weak links in process partners • Rapid change in Technology • Policy requirements

As an overall observation, it was realized that the basic data that drove construction projects are schedules and so the study of technology related issues had to start with a study on how schedules were being created and managed in a few pilot Indian construction sites. So, as a follow up to the workshop, the team decided to a detailed study on three projects and a study of their schedules.

2.1 *Technology Adoption Survey*

On the topic of overall IT adoption for information and equipment technologies, the action team has done a literature survey. Some of the literature available on the topic is listed in the References section below. The team is planning to use the learnings from the studies to conduct a survey on technology adoption status, issues and barriers in the Indian construction industry. The team has created the survey but has not had the time yet to run the survey. The team is planning to run the survey immediately following this consolidation workshop and publish the results in the white paper by December 2016.

2.2 *Scheduling Study*

In today's competitive environments and with the growing complexities of projects as discussed above, planning and scheduling are vital to understanding project performance and is a key to the success of a project. The intended purpose of a good schedule is to assist with proper planning and monitoring of the project. Of course, the schedule has be "enforced" and monitoring has to be done on that schedule to ensure smooth execution of the project. Studies have been done to show that there is a positive correlation to having a good schedule quality (and adhering to the same) with good project performance (Patterson 2011). Noted that there are other factors to project success, but the study noted that good schedule is an essential factor.

Given its vital nature, further studies have been done to assess the quality of project schedules. Today several schedule assessment (both qualitative and quantitative) methods are available (Weaver 2010). Several organizations (particularly in the US) have devised and implemented schedule assessment metrics and standards to evaluate a schedule. Figure 1 shows an example of schedule assessment method and the respective organization that developed the same.

Organization	Publication/guideline title
Department of Defense (DOD)	Over target baseline and over target schedule guide
Department of Defense (DOD)	Integrated master plan and integrated master schedule preparation and use guide
Defense Contract Management Agency (DCMA)	Earned value management system (EVMS) program analysis pamphlet (PAP)
National Defense Industrial Association (NDIA)	Planning and scheduling excellence guide
Project Management Institute (PMI)	Practice standard for scheduling, chap. 6 project time management, fourth edition
University of Texas System Office of Facilities Planning and Construction (UT OFPC)	Project planning and scheduling, section 01 32 00, issuance: September 2007, revision: 3/1/2011 revision
United States Government Accountability Office (GAO)	Schedule assessment guide
National Aeronautics and Space Administration (NASA)	NASA schedule management handbook, NASA/SP-2010-3403
Defense Acquisition University (DAU)	Better schedule performance assessments derived from integrated master plan–referenced schedule metrics
Naval air (NAVAIR)	Integrated master schedule (IMS) guidebook, version 1.0
Center for Earned Value Management (CEVM)	Analysis toolkit

Figure 1: Various Schedule Quality Assessment Method Publications

For our study, three project schedules from owner organizations were selected as pilot for the study. The project types were residential, commercial and an IT park respectively. The schedule assessment was done on the following factors:

Metrics	DCMA Criteria
Schedule logic	The recommendation is that the number of missing predecessors and successors in a schedule should be less than 5%
Usage of Leads and lags	There should be no leads in a network Lags should not be more than 5% in a network
Usage of Floats	The exact definition of high float can be commonly arrived at by studying more schedules. For the purpose 44 days of float is considered (as per DCMA).
Use of Various Types of Precedence Relationships	At least 90% of relationships should be finish to start.
Use of Date (Hard) Constraints	Date constraints should be eliminated in a project schedule.
Resources loading schedules	Resource should be loaded in a schedule in order to realistically reflect the reality
Creating realistic project schedules	Project schedules should consider weather and other uncertainties when determining the dates (start and finish) for activities.

The details of the assessment are discussed in the next section.

3. RESULTS and DISCUSSION

3.1 Technology Adoption Survey

The team has created the points to be discussed in the technology adoption survey. The same will be discussed in this October 2016 workshop. The survey will be run immediately after the workshop and the results incorporated into the white paper by December 2016.

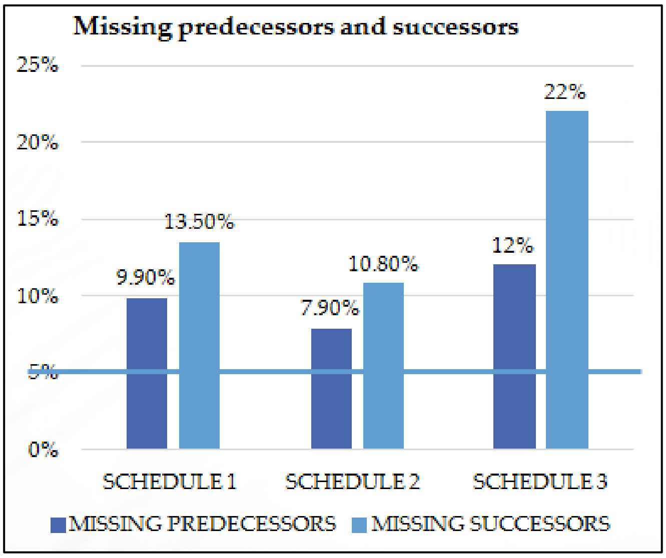
3.2 Scheduling Study

The three identified pilot projects are each of a different nature although they are all building projects. One is a mall, one is a residential project, and one is a commercial IT facility. Details of the project schedules are outlined below.

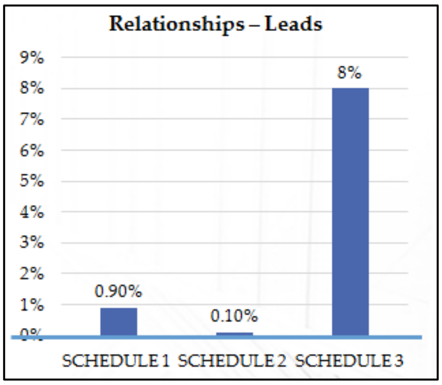
Project number	Schedule 1	Schedule 2	Schedule 3
Type	Mall	Residential	IT park
Total number of activities	2069	1566	10342
Scheduled duration	Nov 15 - Nov 17	Oct 15 - Dec 17	Mar 14 - Aug 16

All the three schedules were created in Oracle Primavera. The analysis of the schedule was done using the methodology used in the Earned Value Management System (EVMS) program analysis pamphlet issued by the US Department Contract Management Agency (see Figure 1 above). The analysis is done on the parameters listed above with a recommendation for improvement.

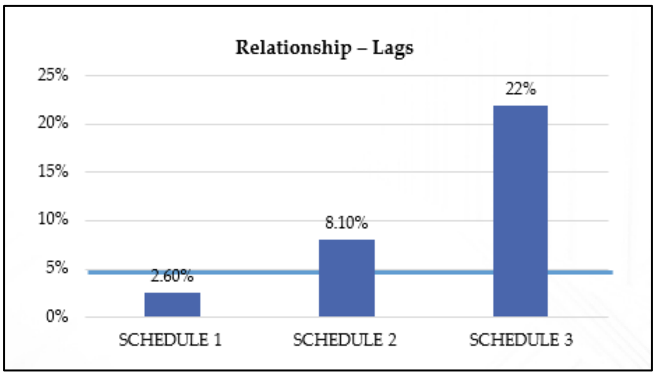
- **Scheduling logic:** As seen in the figure below, all three projects have a number of activities that do not have predecessors and/or successors. A well created schedule should be fully networked to be able to identify the critical path and use the same to monitor the project. The recommendation is that the number of missing predecessors and successors in a schedule should be less than 5%



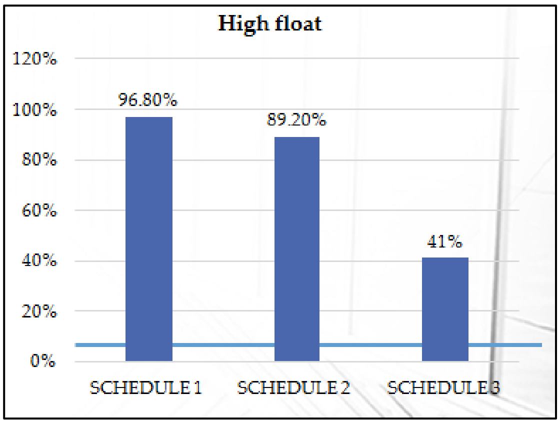
- **Usage of Leads:** Leads indicate the measurement of negative time which are not likely. Presence of leads could potentially result in the successor starting before the start of the predecessor which is not logical. The recommendation here is to <u>eliminate the leads</u> from the network. It can be represented by a positive lag on an S–S relationship or a straightforward, F–S relationships with no lags using smaller-duration activities.



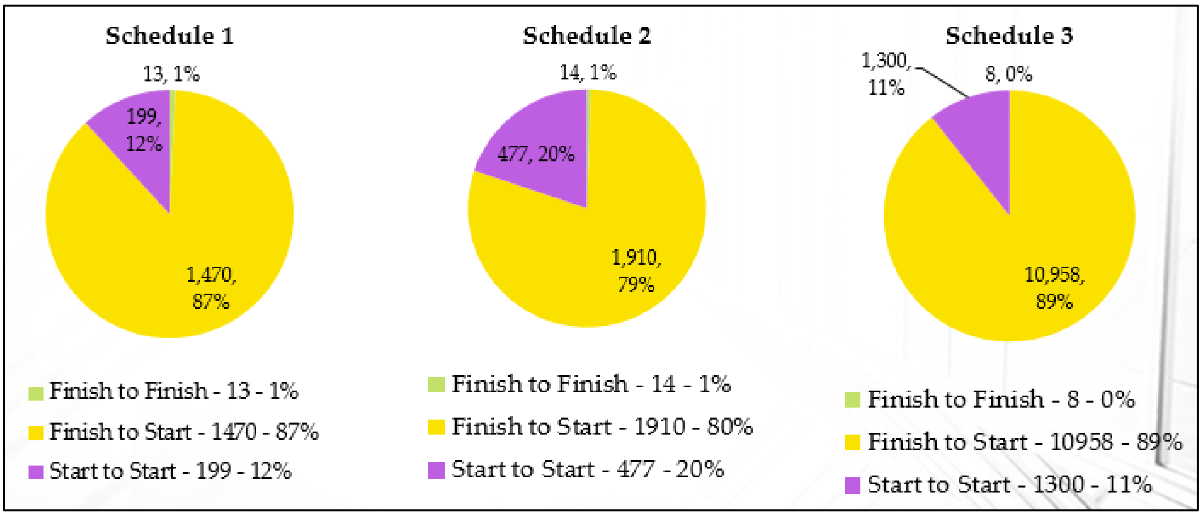
- **Usage of Lags:** Lags are positive durations or delays that delay the start of the successor activity. Their use in scheduling is to denote passage of time of a successor relationship. Lags are often used in a wrong way i.e. –they are used to force the successor activity to start on a specific date. Lags are fixed, i.e. in a network they reduce the dynamic ability of a schedule i.e. to respond to changes in the status of predecessor activities and so the usage of lags must be warranted by convincing reasons in the schedule basis document. The recommendation here that the lags should be <u>less than 5%</u> of total activities in a schedule.



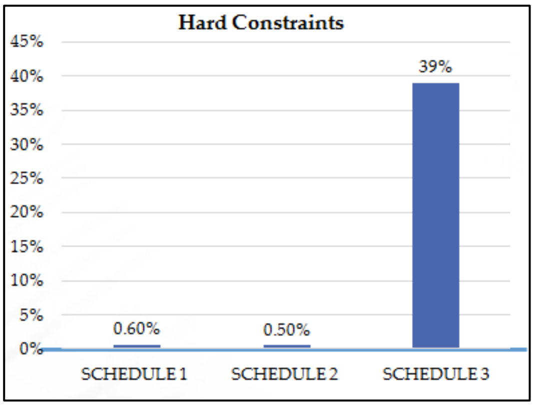
- **Usage of Floats:** Irrational amounts of total float are due to missing logic or broken ends rather than delays that could happen in a project. Therefore activity that has a more floats should first be checked for missing logic. The recommendation here is that number of activities should be <u>less than 5%.</u> The exact definition of high float can be commonly arrived at by studying more schedules. For the purpose of this study, we used 44 days.



- **Use of Various Types of Precedence Relationships:** Ideally schedules should use F-S relationships since they are the easiest to understand and use for managing the project schedule ie., monitoring the project dynamically as the schedule changes. The recommendation is to have more than 90% of the precedence relationships to be F-S type.

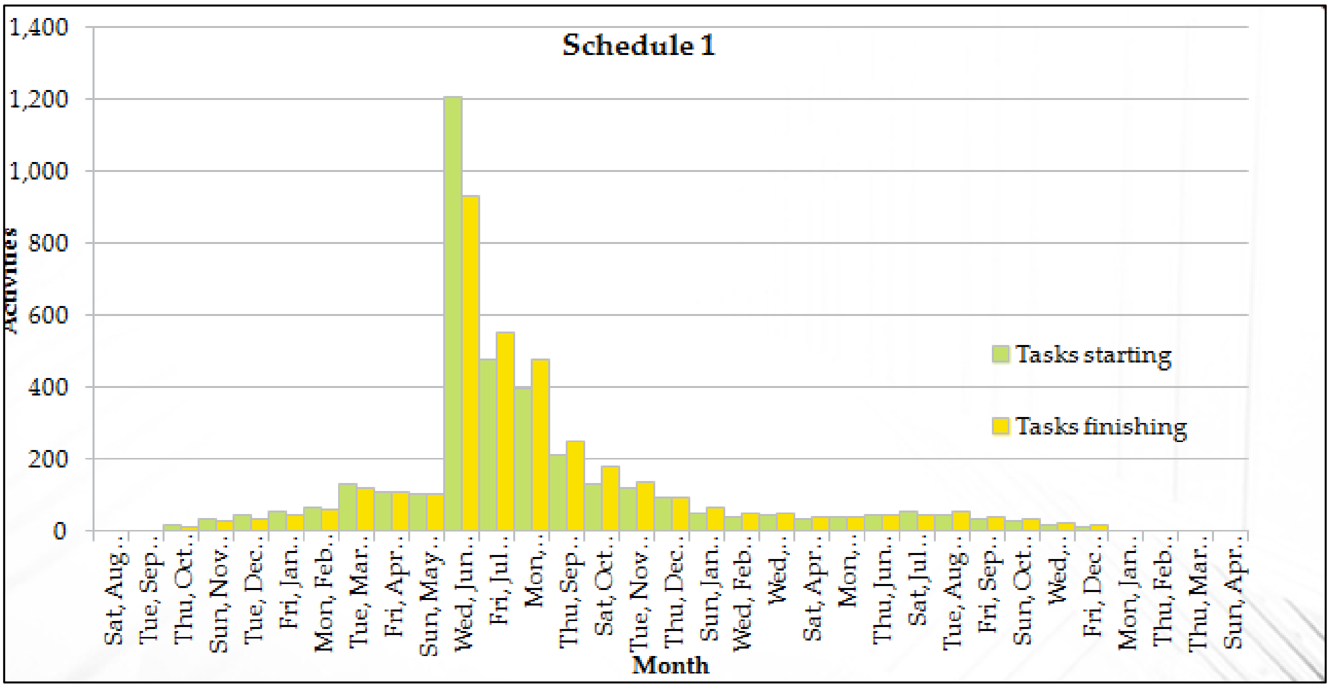


- **Use of Date (Hard) Constraints:** Hard constraints such as Must start on, Must finish on etc. should be avoided as they prevent the schedule from being dynamic. Hard constraints prevent the schedule from moving forward or backward during monitoring of activities during execution. This prevents the re-planning of successor activities in the schedule. The recommendation is to eliminate usage of hard constraints in schedules.



- **Resources loading schedules:** The schedule should ideally be resource loaded to realistically reveal the resources that are needed for the duration of the project. A schedule that has not been reviewed for resource issues is not credible. All three projects did not have resource loaded. Our own assessment is that the resources are loaded, but not incorporated into the scheduling solution in an integrated manner. The recommendation here is to have an integrated resource loaded schedule.

- **Creating realistic schedules:** Creating schedules that can be enforced and monitored on, should take into account the variation in the number of activities being started on a monthly basis. A big variation here will make it practically difficult for the project team to mobilize and de-mobilize resources. Similarly, other factors like weather should be considered in figuring out the number of activities to start per month. For instance, the figure below shows a large number of activities starting in the monsoon period which might not be realistic.



4. WAY FORWARD

4.1 Technology Adoption Survey

The team plans to release the technology adoption survey the week of the Consolidation workshop. The survey will be sent not only to Owners, but also to Contractors, Sub-contractors, Architects, and Engineering Consultants. The team is aiming to get an industry wide survey done in a reasonably large scale to get representative information that can be analysed and presented in the white paper for December 2016.

4.2 Scheduling Study

The analysis of the project schedules based on the metrics have been communicated with the respective project teams and organizations. The team is aiming to work with the organizations in their next projects wherein the recommendations outlined here will be applied. The team is aiming to conduct a workshop at each of the organizations (projects) to sensitise them of the value of a good schedule and describe the parameters used for the same. If the schedule cannot be made "good" on all parameters, the team will work with organizations (projects) to develop a stage wise target to improve the schedule quality. Once the schedule quality is improved the same will be used for monitoring project performance and studying the value of the same in improving project performance. Within the constraints of the availability of projects, the team will aspire to get the work done and report the same in the white paper targeted for December 2016.

5. CONCLUSIONS

Given the ongoing nature of the work, no significant conclusions can be reached at this stage as far as this action item goes. But as discussed earlier, the team is hoping to have data collected, collated, and analysed over the next two months to have a white paper ready for December 2016. The team is hoping to not only analyse the state of technology adoption and its barriers, but also recommend strategies for improving the same over the upcoming years with support from the Ci3 Owner team members.

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