Importance of Moving from Waterfall Methodology to Agile Methodology in Indian Construction Industry

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Abstract. Waterfall methodology as name suggests is a linear progression or sequential development process which flows like a waterfall, i.e. one after the other from beginning till end of the project. Here, the project is divided into phases (like Design Phase, Planning Phase, Execution Phase, and so on) and theoretically one phases started after completion of the previous phase. The project success is measured on achieving the phases within time and budget by attaining the desired quality. Apart from this, there are various KPIs (like Earned Value Management (EVM) or Project Milestones and so on) that are also considered while monitoring the project success.

Indian construction projects more or less follow waterfall methodology which is considered to be rigid & traditional methodology to follow and generally leads to cost and time overruns on almost all the projects. As per the data published in Aug'21 in Business standard, overall cost overrun of as many as 479 infrastructure projects is more than INR 4.4 trillion where each project is worth INR 150 crore or more. Moreover, it was observed that around 541 projects are delayed.

While agile methodology uses continuous iteration method which involves constant collaboration of all the stakeholders in every stage of the project. Thus, implementing agile would make construction projects more flexible where all the changes can be implemented within the allotted timeframes with very less or no re-work involved.

The study will focus on how to use 12 principles & 04 core values of Agile manifesto in construction projects which will yield better results and successful completion of both real estate and infrastructure projects.

Keywords: Waterfall methodology, Agile methodology, Indian construction industry, Scrum, Agile manifesto

Introduction

In waterfall methodology the project teams follow a sequence of steps and do not move forward until the previous phase is completed. Hence, it leaves no space for unexpected changes. If the projects are simple like a 5-floor building construction, then waterfall methodology is easy to follow but for big and complex projects, this methodology will lead to both cost and time overrun as these types of projects generally go through a lot of scope changes which needs additional time and cost to complete. If changes for the previous phase are coming in the current phase, then project team needs to stop the work for current phase and go back to previous phase to implement the changes leading to additional time and effort (Team, 2022).

In waterfall methodology the projects are generally phased based on the "Contractual Milestones" like KD-01, KD-02 & so on and project teams need to achieve first milestone i.e. KD-01 to move to next milestone i.e. KD-02 which makes this methodology more rigid and resist to change. Here, changes happen as per the procedure led in contract agreement which in itself is a tedious task from preparation till approval, the changes are implemented only once approved by the client officially as per the contractual clauses like as per FIDIC Reb book 1999

Clause 13.3 "Variation Procedure" or AIA 201-2007 under Article 7, sub-article 7.2 – Change orders or NEC3 Contract Clause 16.1 "How to manage Change" i.e. issue of Early Warning Notice (Lenehan, 2014).

Waterfall methodology model usage first occurred at the Symposium on Advanced Programming Methods for Digital Computers by Felix Torres and Herbert D. Benington on 29-Jun-1956. This approach was captured by United States Department of Defense in DOD-STD-2167A in 1985 (Sauer202, 2022).

In Agile Methodology, the project is broken into several stages and each stage involve constant collaboration with various stakeholders and this led to continuous improvement. All the changes are implemented as soon as they are raised by the client which make this methodology more flexible and adaptable. Implementing changes quickly in each stage also with continuous improvement leads to save in time and cost for all the stakeholders (Wrike, n.d.).

Success factor for agile can be classified into following: (Buteau, 2017)

- ✓ Organization – Company culture – support from Sr. management and healthy working environment.
- ✓ People – Equipped with project management skills, capable teams, effective communication & stakeholder interaction.
- ✓ Process – Changes are implemented quickly, simplicity in process, timely management of risk, accurate estimates of project resource.
- ✓ Project – Clearly understanding of project type, project nature, realistic schedules followed & realistic budget for the project.
- ✓ Technical – Appropriate agile methodology to be selected for the project, required tools & infrastructure to be provided by the organization, familiarity with the technology to be used for the project.

Research Objectives

Following are the 04 research questions asked from industry experts to understand more about agile and waterfall methodology from their point of view:

HR1: Is Indian construction sector is aware of Agile way of working.

HR2: If yes to HR1, would they prefer Agile working over Waterfall methodology.

HR3: If yes to HR1, waterfall methodology often leads to time and cost overrun on the projects as compared to agile methodology.

HR4: If yes to HR1, in future bigger & complex projects will be easy to handle Agile methodology.

Literature Review

Waterfall methodology is a traditional methodology which have its own advantages as listed below (Dutta, 2021):

1. *It uses straight approach:* All the steps/tasks are pre-defined & clear (as shown in the Figure 2) and since the model is rigid, it's simple to follow. Each stage deliverables are pre-defined and project team is required to follow the same without thinking about it too much (Dutta, 2021).
2. *All the information transferred in a superior way:* All the information is documented and easily accessible to all the team members which ensure smooth & effective transition of information even if a new member joins the project team in middle of the project or a key person leaves the project (Gaille, 2020).
3. *End goal is pre-defined:* Project end goals are pre-defined form the initiation of the project and project team is committed to deliver what is promised as per the contract agreement signed at the award of the project.

4. *Perfect for small projects:* Works completely fine for small/low level projects as project end usage is well-defined & well understood by the project team like construction of residential building (Aiden Gallagher, 2019).
5. *Progress Monitoring:* As each phase start and completion date is already defined either in the contract agreement or in contractual programme, it become very easy to measure progress against each phase (TEAM, 2018).
6. *Risk Register:* At the bidding time i.e. during pre-contract, a risk register is being prepared to assess all the risks and calculate their impacts.

With advantages, there are some disadvantages too which are listed below (Sherman, 2015):

1. All the requirements are not known upfront in the project leads to change in scope a lot as project progresses.
2. To implement waterfall methodology successfully, a detailed WBS programme is required at the starting of the project which is a tiresome task as various activities are based on the team's experience only which usually changes as project progresses.
3. Estimation Errors during bidding time leads to cost overrun on the project.
4. At many times it has been observed that a poor stakeholder communication & disagreeable relationship leads to both time and cost overrun on the project.
5. Since all the design is being submitted after completion, errors in design are generally caught at later stage leads to re-design and delay.
6. Changes are not being implemented quickly as change management procedure is being followed as per contract which takes a lot of time before receiving approval from the client (actiTIME, 2004-2022).

Comparing Agile Methodology with Waterfall Methodology using Agile Manifesto: (Beedle, https://agilemanifesto.org/, 2001)

Sr. No.	Agile Methodology	Waterfall Methodology	Remarks
1	Agile Methodology believes in Individuals and interactions	While Waterfall Methodology works on process and tools	
2	Agile Methodology believes in Working software	While Waterfall Methodology based on comprehensive documentation	
3	Agile Methodology believes in client collaboration	While Waterfall Methodology is based on contract negotiation	
4	Agile Methodology believes in Responding to change quickly	While Waterfall Methodology follows a plan and works accordingly to it	

Considering the above, it can rightly be said that the items listed on left-hand side possess more value than items on the right-hand side.

Understanding more through Agile Principles Vs Waterfall methodology: (Beedle, https://agilemanifesto.org/, 2001)

1) Agile highest priority is to satisfy the client through continuous and early delivery of the product while Waterfall methodology is to satisfy the contract requirements and work on deliverables already defined in the contract agreement leaving client unsatisfied at the end of the work.
2) Agile works continuous towards changing requirement of the client while Waterfall methodology follow the pre-defined method in the contract for any change suggested by the client. Thus, agile harness change for the client competitive advantage while waterfall lag in the same which leads to both cost and time overruns on the project.

3) Delivering the product within the shorter time period for client to review and suggest any modifications while in waterfall the final product is delivered as agreed at the start of the project leaving.
4) Here, both the teams i.e. Project Team and Business team works together daily & throughout the project but once the project is awarded by the client in waterfall, only project teams handles full project, business team involvement is very limited.
5) In agile, Project Manager (PM) motivates the team and develop a very supportive environment without playing any blaming game. Here, PM trust on the individuals for deliverables. While in waterfall, PM creates a fear environment for team to deliver, trust factor is very limited and PM plays politics & blame game in order to get maximum output from the project team.
6) Agile believes that all the information needs to be communicated to the team via face-to-face conversion as it is the most efficient and effective method while in waterfall everyone relies on the email for official confirmation of the work which generally delays the project.
7) The progress is measured in agile on the part works completed and delivered to the client while in waterfall the progress measurement is done based on the pre-approved programme (i.e. Baseline Vs Actual work completed). This progress measurement is rigid and inflexible even more physical work is done but it will only report the work done against the pre-defined deliverables.
8) Agile based on sustainable development which is an alien word for waterfall methodology.
9) In agile, technical work given continuous attention for achieving excellence and overall increases agility of the work while in waterfall, more attention is given to process and procedures and technical is limited to the codes/ specifications specified in the contract agreement.
10) In agile, in order to have more transparency, the maximum emphases is given to the work not done while in waterfall maximum emphases is given to the work completed till date. This information mis-guide Sr. management as PM keep focusing on the amount of work completed till date rather focusing on amount of work balance as done in agile environment.
11) Here, more focus is on self-organizing teams who emerges with the best requirements, architecture and design for the project while in waterfall project team is guided by Project Manager (PM)/ Construction Manager (CM) on the work to be performed daily which kills the innovation and makes project team dependent on the guidance of the PM/CM.
12) Since, project team here is independent, they keep improving themselves and become more efficient & effective by tunning & adjusting its behavior according to the project & client while nothing happens like this in waterfall methodology as team is dependent and not self-organized nor any training is given to them on the same.

When we talk about agile methodology, Scrum also plays a pivot role in implementation of agile best practices perfectly. Scrum guide first version was written back in 2010. Scrum is also used to manage big complex projects with full transparency, inspection, and adaptation when things go outside the acceptable limits. Again, here scrum also talks about the values which should be lived by each individual working under scrum agile environment i.e. commitment, Focus, Openness, Respect and Courage. Scum team only involves 03 type of people i.e. Project team, Project Owner/ Project Manager and Scrum Master. (Sutherland, 2020) So, Agile is a project management philosophy while scrum is a specific Agile methodology. All these aspects are missing in waterfall methodology.

There is no "one size fits all" approach in project management and hence a below table can provide a better picture between both the methodologies: (George, n.d.)

Sr. No.	Waterfall Project Management Methodology	Agile Project Management Methodology
1	Lot of changes are excepted from initial accepted project scope as per contract	Changes can occur as project progresses
2	As per mutually agreed contract, a clear idea of budget, scope, resource, and time is there	Budget, scope, resource and time could change along the way
3	Most important is that the final product should be same as planned initially	The final product can differ from the initial accepted scope
4	Rigid and traditional approach	Flexible and modern approach
5	Since critical path is already decided initially, it is unlikely to change	Here, priorities can change, and project team will adapt accordingly
6	The project can be divided into smaller phases, but the overall plan required to be followed as mutually agreed with the client	Here, overall plan can change and become irrelevant as project progresses
7	Client involvement is limited, and more focus is on the project monitoring and controlling	Client involvement is high as client tis involved throughout the project
8	Progress monitoring is quite easy as it is well documented & measure against the baseline	Minimal documentation is done & progress measured against minimum Viable Product (MVP)
9	Project success is measured in terms of completion of project as per contract & within budget & time allocated for the project	Project success is measured on the final outcome as desired by the client

Example of how a construction project works based on Waterfall Methodology:

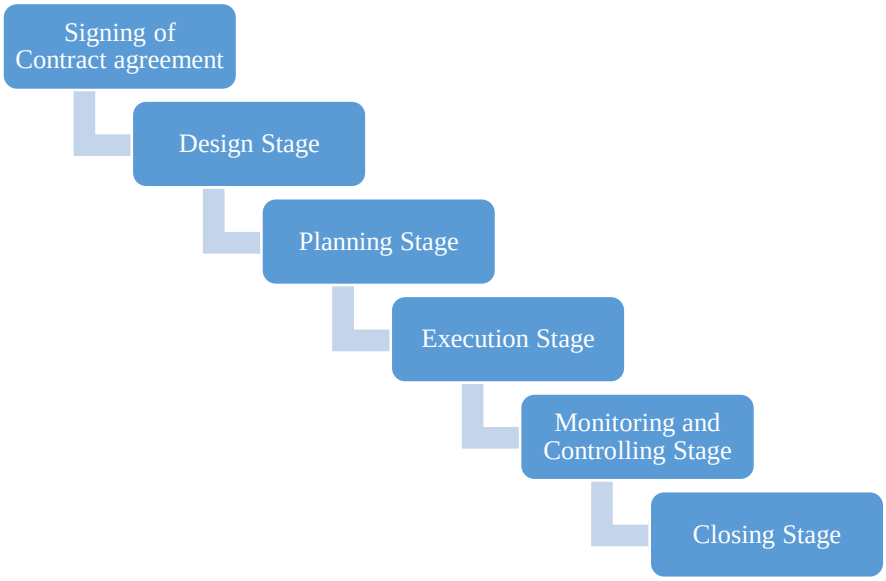


Figure 1: Construction Project based on Waterfall Methodology

To understand a simple construction detailed design (DDC) project based on Waterfall Methodology, an example is given below where Key Dates (KD) are defined in the contract agreement:

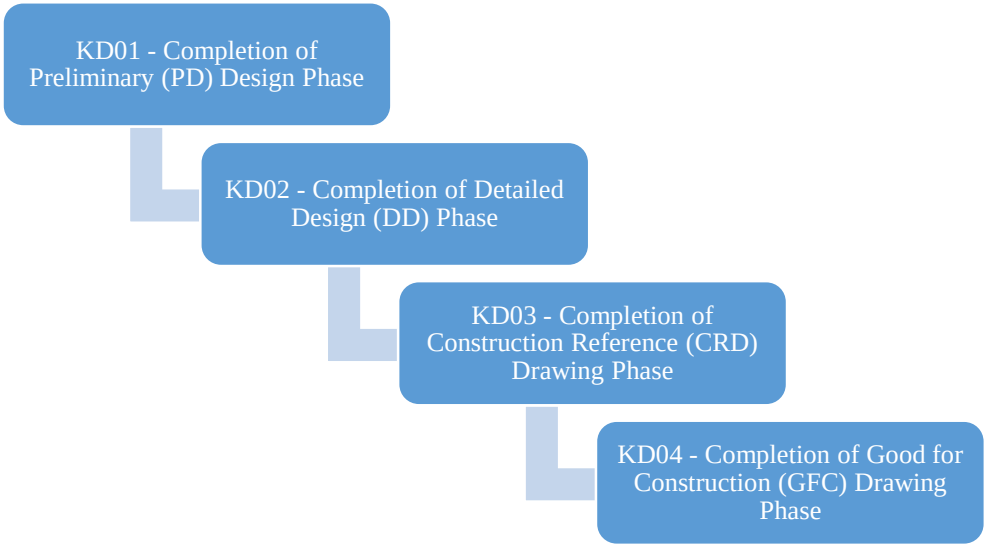


Figure 2: Construction Design Project based on Waterfall Methodology

Example of how a construction project works based on Agile Methodology:

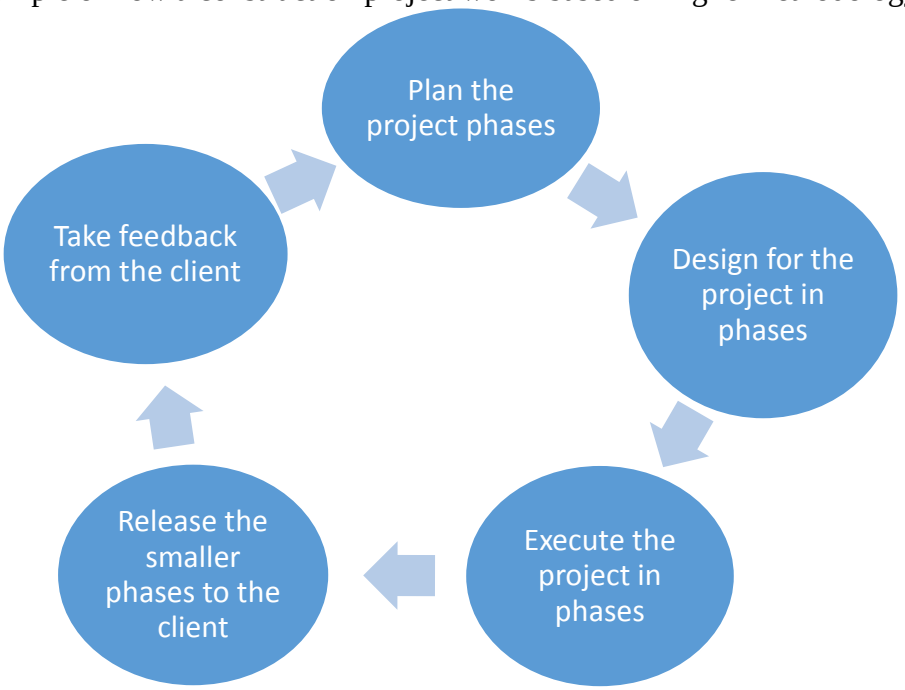
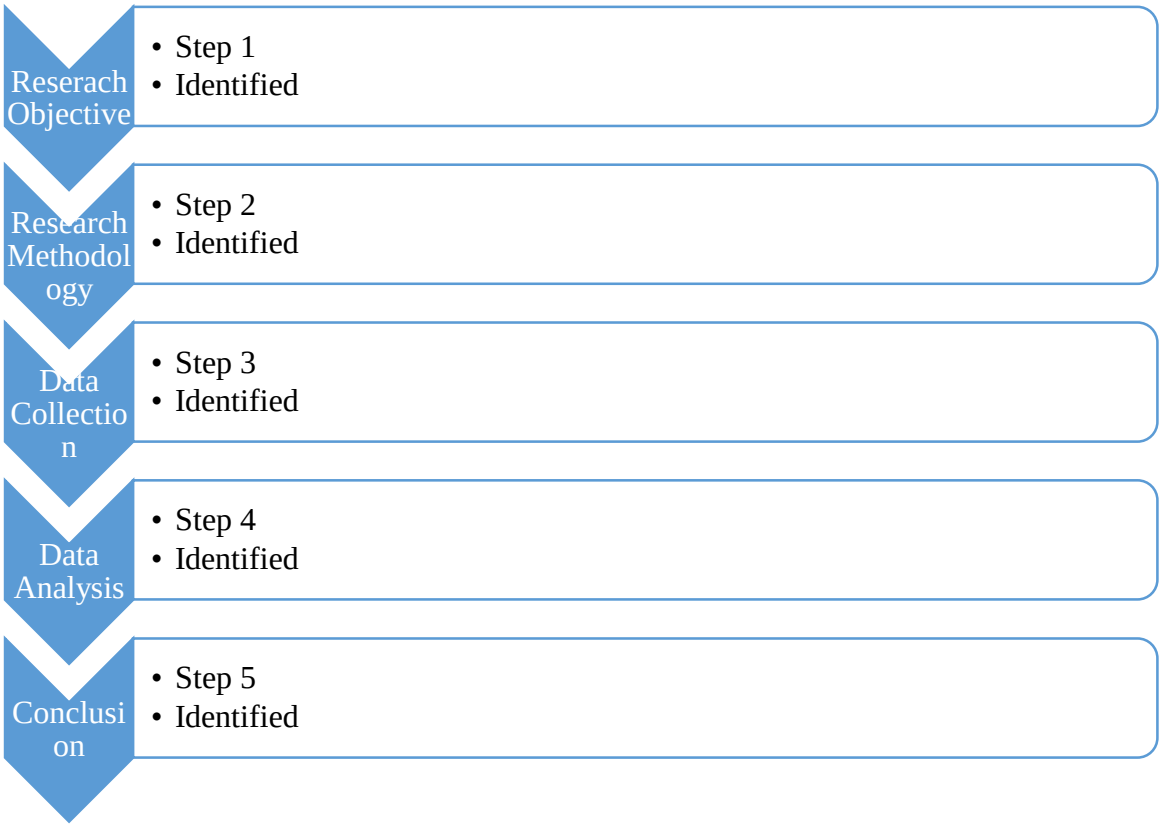


Figure 3: Construction Project based on Agile Methodology

So, waterfall is more like moving forward after completing each stage while in agile the developer keeps coming back to enhance the project phases based on the feedback received from the client.

Following workflow adopted in this research paper:



Research Methodology

The research methodology used here is Quantitative. Both Primary and secondary data was used to analyze the data and interpretative the findings.

Secondary data generally consists of data previously gathered by the scholars and it can be now accessed by the researchers. Secondary data helps in increasing the sampling size of the research work & also increases the efficiency and speed of the research as the work on the same has already been by the previous researchers (Contributor, 2017) while primary data consist of the work generated by the researcher themselves (Wagh, 2022).

Here, a questionnaire survey was carried out among the 140 respondents. These 140 respondents via interview highlighted the 05 biggest issues faced while using the waterfall methodology. Apart from this, their responses were collected via email on the questionnaire survey that was circulated consisting of 04 questions.

Nearly all the respondents are from the construction field and expert in their roles. Respondents included planning managers, project controls managers, construction managers, project managers, QA & HSE mangers, site project team and sr. management. Respondents that were selected for this research were from different type of companies working in construction field like contractors, clients, consultancies, and sub-contractors/sub-consultancies.

Since, the respondents selected to answer the 04 questions raised in the questionnaire survey were from ‘different type of organizations’ and ‘working at different designations’ in those organizations increases the authenticity of this research finding. The respondents considered here were having experience ranging from 05-25 years of handling construction projects and more than 90% of the respondents were from Infrastructure heavy civil projects as these projects are more complex in nature. Thus, increase the reliability of the findings.

% Respondent's organizations wise break-up:

Sr. No.	Respondent Company	% Respondents	Number of respondents
1	Contractor company	35%	49
2	Client company	30%	42
3	Consultant company	25%	35
4	Sub-contractor company	06%	08
5	Sub-consultant company	04%	06

% Respondent's designation wise break-up:

Sr. No.	Respondent Designation	% Respondents	Experience in handling construction projects
1	Sr. Management	09%	Between 20-25 Years
2	Project Controls Manager	17%	Between 15-20 Years
3	Planning Manager	19%	Between 10-15 Years
4	Project Manager	23%	Between 15-20 Years
5	Construction Manager	18%	Between 10-15 Years
6	Site Project Team	14%	Between 05-10 Years

Data Analysis & Findings

The respondents highlighted below 05 biggest issues faced while using the waterfall methodology.

Issue No.	Issues faced while using the waterfall methodology	% Respondents	Number of respondents
N_1	Deadline Creep – Delay in one phase, automatically delay the successor phases.	31%	43
N_2	Change Management is very tedious & tiresome process.	23%	32
N_3	Unpredictable changes invalidate the work done in the previous phases.	19%	27
N_4	It leads to extension of timelines and additional cost as every phase require 100% completion before moving to next phase.	14%	20
N_5	Often leads to Liquidated damages and penalties for not achieving contractual milestones on time.	13%	18

To cross verify, Relative Importance Index (RII) is deployed to determine the relative importance of the factors highlighted by the respondents. (Harsh Saxena, 2018)

Weightage range from 1 to 5 where,

A = the highest weightage i.e. 5

N = total number of respondents

W = Weighting as assigned on Likert's scale by each respondent in a range from 1 to 5 where,

1 = Least importance

2 = Low Importance

3 = Medium Importance

4 = High Importance

5 = Extremely Significance

RII value will range between 0 and 1, the higher the RII value the more important delay factors highlighted by the respondents.

Following formula is used for calculating the RII:

$$RII = \frac{\sum W}{A \times N}$$

Frequency Table:

Sr. No.	Issues faced while using the waterfall methodology	Extremely Significance	High Importance	Medium Importance	Low Importance	Least importance	Frequency
		5	4	3	2	1	
1	N_1	50.00	45.00	33.00	7.00	5.00	F1
2	N_2	49.00	44.00	33.00	8.00	6.00	F2
3	N_3	47.00	41.00	32.00	10.00	10.00	F3
4	N_4	45.00	39.00	29.00	13.00	14.00	F4
5	N_5	40.00	35.00	30.00	18.00	17.00	F5

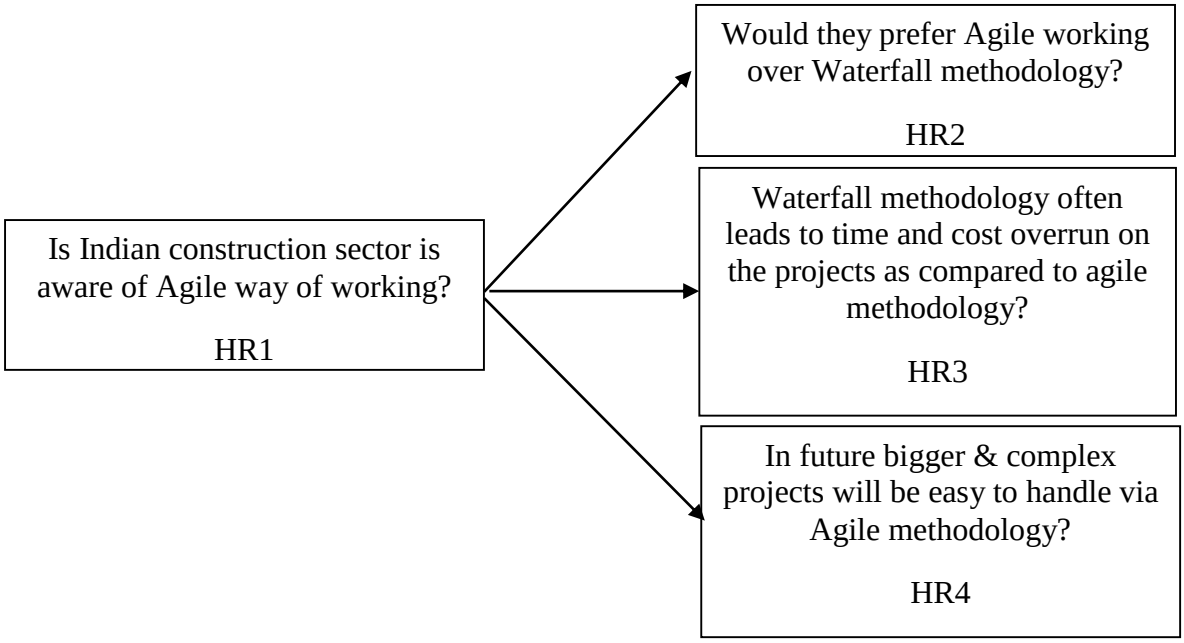
RII & Rank Table:

Sr. No.	Issues faced while using the waterfall methodology	ΣW = 5*F1+4*F1+3*F1+2*F1+1*F1	A*N = 5*140=700	RII	Rank
1	N_1	548.00	700.00	0.7828	1
2	N_2	542.00	700.00	0.7742	2
3	N_3	525.00	700.00	0.7500	3
4	N_4	508.00	700.00	0.7257	4
5	N_5	483.00	700.00	0.6900	5

This concludes the following:

A. Issue No. 1 holds “Extremely Significance” as a factor causing delay while using the waterfall methodology.
B. Issue No. 2 holds “High Importance” as a factor causing delay while using the waterfall methodology.
C. Issue No. 3 holds “Medium Importance” as a factor causing delay while using the waterfall methodology.
D. Issue No. 4 holds “Low Importance” as an issue faced while using the waterfall methodology.
E. Issue No. 5 holds “Least Importance” as an issue faced while using the waterfall methodology.

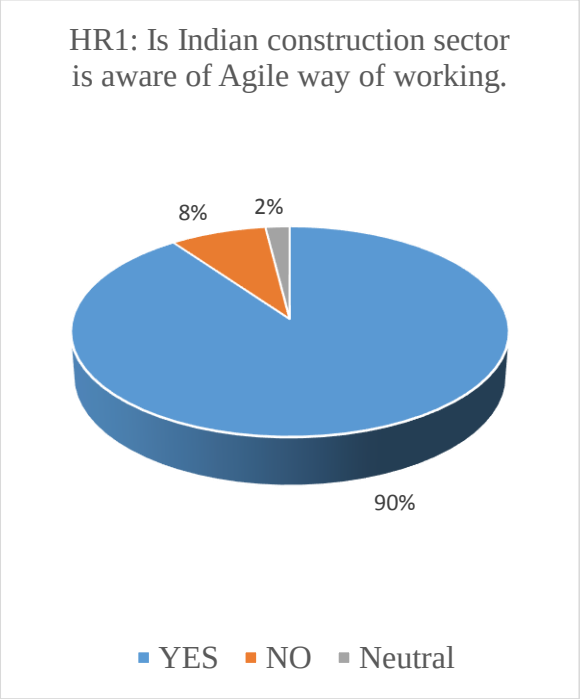
Conceptual Framework – Interrelation of HR2, HR3 & HR4 with HR1:

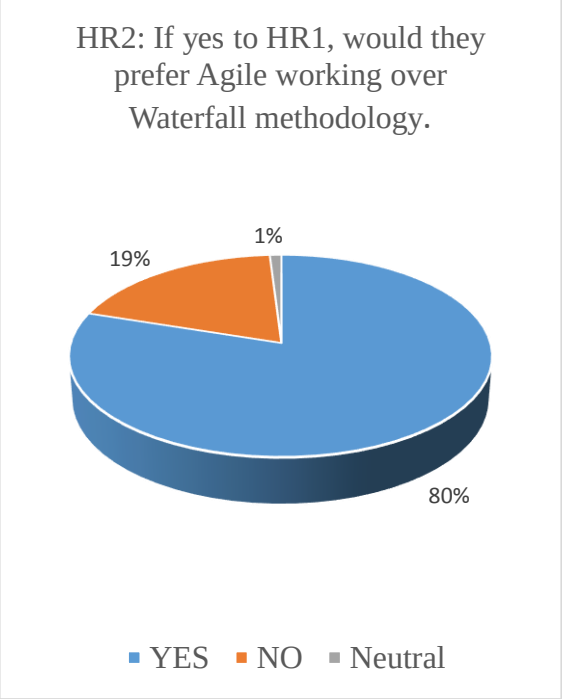


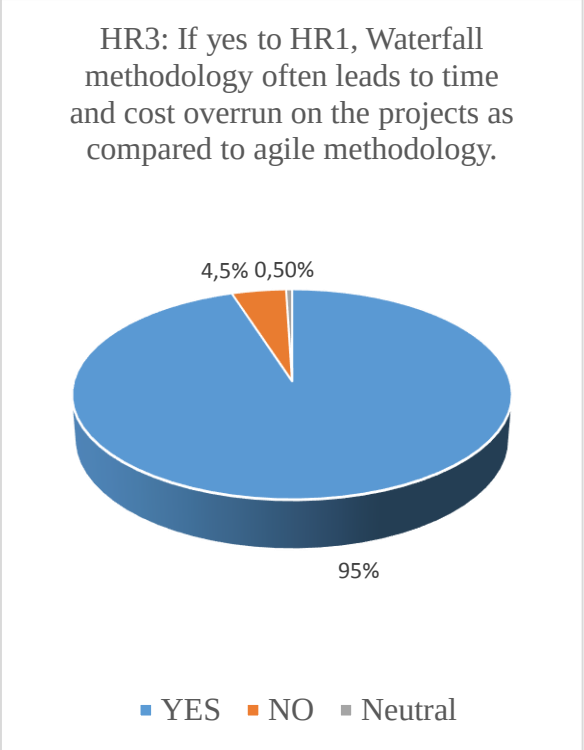
From the analysis of questionnaire survey following were observed:

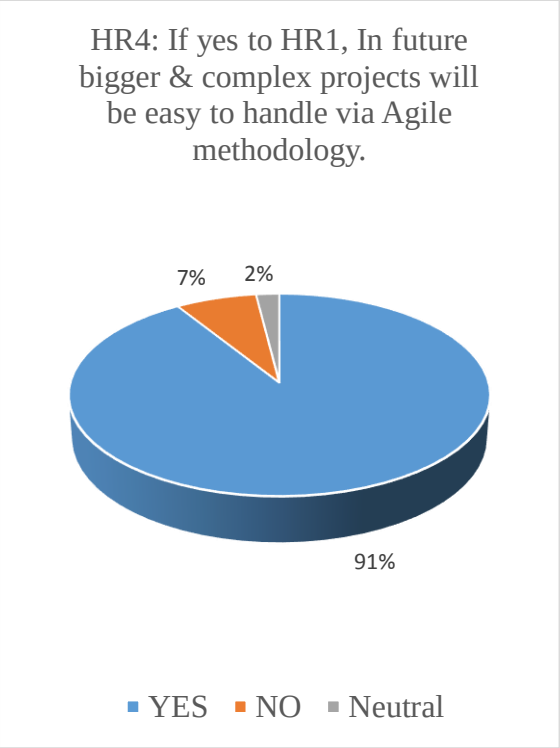
A. 90% respondents are aware of the agile methodology.
B. 80% respondents agree to use agile over waterfall methodology.
C. 95% respondents agree that waterfall methodology leads to cost, and time overrun as scope change is difficult to manage.
D. 91% respondents believe that for big & complex projects, agile methodology is more suitable than traditional waterfall methodology.

The respondent's responses are recorded in the form of pie chart:









Discussion and Conclusion

Waterfall methodology has its pros and cons and the same been discussed here. Agile manifesto along with agile 12 principles were also explained in reference to waterfall methodology. It's not easy for the project team to simply switch from waterfall to agile after being worked in waterfall environment for so long.

The world is changing and so the construction projects. Waterfall won't disappear but more and more focus is moving towards performance indicators, motivation, self-managing teams, openness, respect which are more tilted towards agile way of working.

If adopting fully agile is not possible then, it's time to move from "Pure Waterfall model" towards "Modified Waterfall model" i.e. waterfall mixed with agile model which will result something like waterfall with overlapping phases/ stage (Wikipedia, 2022).

Waterfall methodology is more suited for projects where low uncertainty exists. It is typically more expensive as compared to agile working environment.

The problem lies with the Indian construction projects is that from initiation of the project waterfall methodology is being followed but when execution is in progress partial agile methodology comes into play i.e. lot of changes keep happening as per client instructions without any change order being prepared by the Project Manager nor Project Controls department being informed about it. Since, the contract is signed with fixed fee, all these changes lead to additional cost which is not being recovered from the client leading to cost overruns on the project.

Hence, we can conclude that modified waterfall model can be used upto certain extend but to successfully complete the project it is always recommended to follow single methodology from inception till completion. Agile considered to be much more appropriate and logical for successful implementation of todays' mega construction projects. A truly homogenous mix of agile and waterfall isn't viable (Shultis, 2019).

Lastly, organizational structures of various construction companies are optimized for waterfall methodology. Project teams are more skilled at technical knowledge & lacking in broad skills needed to implement agile. Attitude of Sr. Management including project team

needs to shift from waterfall rigid working style towards openness flexible agile working style. The staff should be trained into project management philosophies including agile & scrum.

By making system more transparent by agile model implementation, corruption will also be likely to come down. There will be a big relief to the project team from the continuous pressure created in waterfall methodology by implementing agile way of working. Work life balance, which is missing in companies working on waterfall methodology, can be brought back by implementing agile methodology.

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