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FRAMEWORK OF INTERACTION BETWEEN ICT, PROCESS, AND PEOPLE IN CONSTRUCTION: A CASE STUDY

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ABSTRACT

The construction industry is often criticised for lacking a holistic view on applying Information and Communication Technology (ICT) to improve project efficiency. Integration of the three core organisational aspects of people, process, and Information Technology (IT) must be realised to bring true benefits in construction project delivery. However, the industry has not yet reached significant maturity in achieving this synchronisation.

The research follows a case study-based approach where the authors were involved in the implementation of an ICT solution that helped streamline project planning and execution through effective collaboration on a Data Centre retrofitting project in USA.

The research demonstrates the importance of effective communication through efficient information management by deploying ICT which helped overcome inherent process inefficiencies and challenges on the case study project. Based on the observations, the authors have proposed a framework that highlights the interaction of ICT, people, and process, and mapped the results achieved on this project through their integration.

KEYWORDS

Construction management, information & communication technology, process management

INTRODUCTION

It is a significantly evidenced fact that construction projects are still struggling to deploy well-structured processes and automated workflows and tend to resist adoption of technology (Dave et. al., 2008). While ICT has proven to enhance collaboration and integration amongst stakeholders, rigid conventional processes and latent information continue to prove incompetent in addressing the rapid changes in design and environment leading to catch-up planning (Martinez et. al., 2017).

While there is evidence that ICT adoption has enabled project performance by changing the processes, successful implementation of any tool or process requires acceptance and involvement by the people involved in the project (Dave & Koskela, 2009). Research has highlighted the importance of reviewing Business Processes with a need to focus on integrating people with change management for the successful implementation of IT in construction (Dave, 2017). However, there is not enough evidence on the nuances of team culture and process change that have helped in effective deployment of ICT to improve project delivery.

Past studies primarily comprise of individual cases where the success and/or challenges of adoption of ICT towards improving project efficiency have been documenting, while highlighting the importance of integrating the essential aspects of people, process, and

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technology. However, these studies are often limited to case-specific observations and conclude with the importance of integrations of the three verticals without any specific clarity or structuring on the "how". These studies provide limited exposure to readers in terms of extrapolating these learnings into a broader methodology or framework that can widen the spectrum of the observations while also providing clarity on the integration and interaction of these critical aspects. The paper here addresses this gap by utilising the observations from this case study towards developing a structured framework that can guide fellow practitioners to take the first steps towards integrating people, process, and technology effectively.

While ICT has played a crucial role in streamlining construction project delivery, the research here dives deep into understanding where the improvement stems from, i.e., the tools adopted, processes that structure and enable participation, and the project culture that drives interaction of people in the teams. The authors believe that a framework will not only guide the industry towards more effective deployment of ICT but will also help them better understand the nuances of their own observations through this structured approach as they deploy this on further projects.

LITERATURE REVIEW

Construction continues to remain a fragmented industry with each participating team bringing in their unique experience and technical expertise. Dave et. al. (2008) highlight the negative impact of this structuring on the project culture which tends to create friction between teams and isolation of information.

Information Management Systems (IMS) have proven to play a critical role in enhancing collaboration within projects (Craig & Sommerville, 2006). Nigel and James (2006) have highlighted the role of IMS in efficient collaboration between the Architect, main Contractor, and sub-contractor leading to successful delivery of an office refurbishment project. A cultural shift towards information sharing was developed through this integrated approach using IMS. Effective collaboration has helped drive efficient decision making for project planning and control (Dave et. al., 2014; Cheng et al., 2013).

ICT continues to help drive improvement and efficiency in construction project delivery. Ambuja et. al. (2013) discuss the use of ICT in providing historical information of previous jobs that helped balance the supply and demand for accurate daily and weekly planning for a mechanical contractor. Mobile tools have a direct impact on decision making efficiency through instant access to accurate and timely information (Harstad et. al., 2015).

Martinez et. al. (2017) have evidenced the benefits of visualisation from ICT in reducing lead time through improved communication from effective information sharing for a large-scale affordable housing project. Visualisation offered by 3D & 4D CAD technology has enabled teams to take effective engineering and design decisions (Khanzode et al., 2005; Rischmoller and Alarcon, 2005).

The characteristics of ICT play an important role in driving project culture in the right direction. Tools that enable participation through simplicity and ease-of-use enable information sharing (Dave and Koskela, 2009) which allows for better integration between project teams (McHugh et. al., 2019).

ICT also has the potential to provide completely disparate versions of the same truth when disconnected sources of information are left open to interpretation by teams in isolation. Effective deployment of ICT must ensure a cross-disciplinary capture and reflection of data across all project teams to develop a shared understanding of product-organisation-and process design (Fischer and Kunz, 2004). The interface between people, process, and IT are the critical points to ensure successful implementation of ICT in construction (Rischmoller and Alarcon, 2005).

The literature reviewed highlights the importance of accurate information exchange and efficient communication in the construction industry, and the role that technology plays in making the process more streamlined and effective. Inefficiencies are common across projects in the industry with a false expectation from technology to deliver instant benefits on projects. The fact is that cultural change and process alignment are the foundations for adopting any new technology (Harstad et al., 2015; Ahuja et al., 2009).

RESEARCH METHODOLOGY

The research is built on a case study approach where the authors were involved in the implementation of ICT (*VisiLean* tool for project planning, execution and monitoring) in the project. The authors helped deploy the ICT tool by working closely with the project management consultants appointed by the client for this project. The authors' participation on the project was in direct capacity through involvement in planning and review meetings while ensuring the tool is used effectively based on the project team feedback and discussions during these meetings.

The case study focuses on the critical factors of ICT for enabling efficient information exchange and effective communication with a keen focus on the accurate alignment of project culture and processes.

Based on their observations, the authors have developed a framework of ICT, people, and processes, to map the interactions and results documented on this. The intent of the proposed framework is to provide a matrix of reference for project teams exploring benefits from ICT, as well as allowing researchers and industry to further contribute to the framework by adding their observations and results from other ICT implementation.

CASE STUDY

The case study is of a retrofitting project at a major data centre in central San Francisco. The project involved the replacement of 10 Power Protection UPS (Uninterruptible Power Supply) units, that provide emergency power backup in the event of a sudden blackout (complete loss of power) or a brownout (temporary dip in voltage). These units are critical to ensure reliable 24x7 operation and protection of the hardware and file systems housed in these data centres.

The project client onboarded a project management and consultancy business in USA, with extensive experience of working on time-constrained, technically complex Data-Centre projects, cloud providers, and their supply chains, to help drive performance improvement through efficient project management methodologies that help streamline construction project delivery.

Various ICT solutions were adopted in this project, amongst which a tool called *VisiLean* was onboarded by the project management consultant for enabling collaborative planning and production control. The authors participated on this project by providing active support for the implementation of this ICT tool, *VisiLean,* by facilitating various collaborative planning and review sessions and working with the project team to ensure the implementation of ICT is aligned with their requirements.

PROBLEM DISCUSSION

The onboarding of an expert consultant along with the ICT solutions was a gradual approach towards overcoming the challenges specific to the project. The major challenges have been documented below to give context to the inclusion of ICT and the benefits achieved therein.

Installation of a new Product

The supporting contractors had no prior experience or background to install this type of equipment. With completely new configuration and operational procedures, without any guidance from the supplier, the team had to carefully understand and develop a strategy to

transport, install, and test this equipment. This is also why the Client introduced an expert consultant with prior experience in working on mission-critical data centre projects.

Environmental Factors

The Data Centre was housed in the top-floors of a space constrained building in a congested street with limited access. Further, the Data Centre had to continue operations throughout the replacement of the units, maintaining uninterrupted service to customers across the globe customers. COVID -19 added further restrictions in terms of reduced manoeuvrability inside the building and additional cleaning of spaces and equipment, with stringent protocols to abide by. Simple operation of getting people in and out of the facility had to now follow specific paths and hallways, proving to be quite challenging.

Management of a diverse Team

The team deployed on the project had no past interaction or experience of working together. Everyone came with their unique culture with varying perspectives on technology. The different levels of exposure to ICT ran across a very wide spectrum – while some people were familiar with advanced 3D and CAD technologies, the others were still used to a paper-and-pencil approach. Further, while some teams believe in a data-centric project delivery approach, this team was more used to a people-centric approach, i.e., driven and lead by a key person who takes charge and defines the processes.

Information Management Challenges

With the onset of COVID and the limitations to physical interaction, the dependency on sharing information remotely increased significantly. Conventionally, the reliability of information the project team was presented with was also highly questionable. Further, the scope of information was also very limited, because of which a lot of assumptions would have to be made.

Due to a lack of common understanding between project teams, information was usually misinterpreted. Understanding of the problem statement varied across the project team, since there was no single source of truth, or common understanding of the data available. A combination of limited communication, lack of common understanding, and poor or inaccurate information led to ill-will and a culture of blame game. This created a toxic environment of negativity and uncomfortable conversations, which leads to people hoarding information.

It was difficult to collect everyone together physically in the same place at the same time. This led to limited interaction between project teams, leading to high social and trust barriers, limiting the scope for deeper, rich, conversations.

PROBLEM RESOLUTION WITH AN INTEGRATED APPROACH

Given the nature of the project and problems identified, the project team was pushed to evaluate ways to overcome these challenges to deliver the project within time and budget. Building on these challenges, the team was able to clearly define a set of requirements for which various ICT solutions were onboarded. Supporting this deployment was the expertise provided by the consultant that was able to curate the adoption of ICT with the right changes in processes by working closely with the teams at the ground-level to help build a culture of participation and good-will towards the project.

With the onset of COVID, the now dispersed project team shifted to connecting remotely by having their project meetings online. The teams could no longer be always present physically at the site for logistics planning as well. Online platforms were chosen to stay connected with the people as well as the site. Laser scans of the facility were used by the teams to virtually manoeuvre through the project site for accurate logistics planning by gaining a clear understanding of the environment challenges. The team was able to visualise the product and process design to develop an installation strategy with accurate information about the facility

from these scans, and detailed specifications of the units to be installed. The project team had technical experts from Netherlands, Texas, Washington State, etc. who could join these meetings effortlessly. This helped the team accelerate the process of problem resolution and decision making.

To ensure effective information management even through remote connectivity, the teams deployed a Common Data Environment (CDE) where all project data was stored, barring financial information. Every project member was provided access to the CDE platform - Autodesk® BIM360™ a cloud-based platform which hosted design specs, facility layouts, etc. The intent was to democratise the information, ensuring everyone has access and visibility to all the project related data. The teams would mark-up 2D drawings, design documents, etc, for planning discussions and further information to develop a common understanding of the execution strategy. This was then discussed during the online meetings, so that the entire team was aware of the changes and the comments.

VisiLean, a cloud-based platform was deployed replacing Microsoft Excel® and sticky-note planning to collaborate with teams for accurate production planning, live monitoring of execution, and project control. With real-time updates from site on VisiLean providing clarity on work status, the team could take ownership of the tasks to be executed, and make any adjustments live with the entire team.

The visualisation of the production plan and the environment information gathered through the laser scans and live updates helped in understand the status of the job there. With synchronised information for everyone, the team was able to develop a common understanding of how the work can be executed in the best possible manner. Having this visualisation of information from ICT helped choreograph the sequence of event in sync between all trades with the right timing.

The team was able to drive efficiency in their use of project assets by understanding each phase and optimising the work and resources in sync to mitigate any risks. This approach helped provide evident savings in labour spend and direct cost to the facility owner.

Results Achieved

It is essential to evaluate the post implementation of such tools for continuous improvement. Hence, the implementation of these ICT solutions and process changes within the project team was evaluated to come up with the attained results discussed below.

- **Mistake proofing:** The team was able to limit human error and variability to ensure the project are developed as intended/designed. With ICT, the team moved away from a very paper and people driven approach which removed the heavy dependency on limited human resources for information. By reviewing the data live and together on a common platform, the team could come to consensus democratically. This proved to be transformational for the project by ensuring minimum surprises on-site and completely removing a blame-culture.
- **Information Transparency:** The project team utilised the CDE as the collection point for all project documentation – drawings, schematics, laser scans, etc. This helped develop the idea of one-team amongst the people. Once the team unravelled how one's work impacted the other down the line, it made a huge difference in their approach to planning. This was done through transparency achieved from using VisiLean, which made these relationships clear and evident to the project team.
- **Visualisation:** Laser scans of the facility were added to the CDE to overcome the environmental constraints mentioned earlier. Project teams could access the entire facility though the scans remotely, visually survey and navigate through the spaces, to figure out the best way to approach the job. They could work out the ingress and egress accurately to work out the exact path for manoeuvring the equipment.

- **Single Source of Truth:** Having access to all this project information without gate keepers made it the single source of truth. In fact, the more people used it and contributed to it, the more information flew into it, thereby creating an approach of sharing, rather than hoarding information. The more one contributes to this information, the more valuable they become to the team, creating rich participation and collaboration.
- **Integration:** The teams would connect remotely using Zoom and other video conferencing tools that enabled them to work from their home offices. This way, even more data came flowing, with technical experts joining from Netherlands, Texas, Washington State, etc. The teams could leverage these tools for clear, valuable conversations, by looking at the same information – the single source of truth. This way, the team could develop a common understanding of the project, common reality, by clearly visualising what the challenges would be, mark them up on drawings, scans, and layouts using ICT, and do all of this remotely, saving the cost of bringing these experts on site. All this information would be transcribed back to the CDE as a captured log of discussed information, following which the tool would automate the process of disseminating this information to the relevant actors for further action.
- **Performance Improvement:** With the installation of each unit, the team was able to review their workflows for its successes and failures, from real-time updates captured on VisiLean from the project site. With this information, the team could review the scope for improvement and then discuss this analysis collaboratively to optimise the sequencing of activities for the next unit.
- **Collaboration:** The team was most successful in realising the importance of adjusting their processes according to the technology deployed. Their primary view was data, and to harness it most effectively, the team focused on revising their processes towards how the data was received, processed, and analysed. The teams started to overcome barriers to technological maturity by getting everyone together and developing a sense of comfort by discussing experiences and backgrounds. Once a level of trust was established, the introduction and absorption of the tools deployed on the project became less resistive.

PROPOSED FRAMEWORK & INTERACTION MATRIX

The results achieved on this project were a direct outcome of process and cultural changes adopted by the project team complimenting the deployment of the ICT solutions. To elaborate on these findings, the authors have proposed a framework that is built on the interaction between people, process, and technology towards streamlining construction project delivery through improved processes, better project culture, and ICT enabling these results.

From the case study, the value propositions attained from the people and process aspects, along with the various ICT solutions used on the project have been highlighted as a matrix of interaction in the proposed framework (**오류! 참조 원본을 찾을 수 없습니다.**). The interaction matrix acts as a frame of reference for the industry to apply on their projects towards overcoming specific challenges with the help of ICT, while coupling it with the right value proposition from the process changes and project culture.

The value propositions have been derived from the case study observations and results achieved. These have been then categorised by the authors between the aspects of people and process, based on their respective characteristics and alignment. For example, *clear communication* is an aspect of a *process* where information is structurally shared, while the *ownership of that information* cannot be guaranteed by the process; it is an aspect of *people* and their sense of responsibility towards that work and information.

Similarly, while a production management tool can prove to be very effective, it cannot guarantee *clear communication* till the *people* utilises the tool through an online meeting platform to discuss through *rich participation*. However, with *clear ownership*, the tool can guarantee a *sense of appreciation* for the *people* since their progress, work, and contribution is now clearly documented and visible to all.

It is through these various lens that the authors have layered this intricate framework of interaction together to map out a structured approach towards arriving at attainable project outcomes. While neither of the three components are exhaustive and all-encompassing, they are true to this project and a step towards their further applicability on projects across the industry.

Specific to the case study, the interactions have been mapped to highlight the benefits attained from the ICT adoption and the interaction of people and process therein. As an example, drawing on the adoption of a CDE platform, the project team was able to establish clear communication, democratise information and decision making, and understand the impact of work between trades. This helped develop a sense of appreciation, trust, and enable the contribution and ownership of information, which in turn created a positive work environment. This enabled complete information transparency between the project teams, thereby making CDE the single source of truth for the project.

Similarly, to overcome remote connectivity and limited access to the project site, the team used laser scans to develop a common understanding of the facility to help prepare for the logistic challenges by visualising the sequence of work better. This work clarity helped in reducing assumptions, thereby allowing the team to make effective decisions despite barriers to physical interaction.

The proposed framework is open to addition by the industry from their experience of value attained in processes and cultural aspects on their projects based on ICT solutions implemented. The goal of this framework is to offer flexibility and scope for further development in future research, by both industry practitioners, as well as fellow researchers.

Table 1: Framework & Interaction Matrix of ICT, Process, and People

ICT	VALUE PROPOSITION	Common Data Environment (CDE)	Markups on 2D layouts	Laser Scans	Online Meeting Platforms	Production Management Tool
PROCESS	Clear Communication	X			X	
	Democratising information & decision making	X	X			
	Understanding impact of work between teams	X			X	
	Shared view to problem solving		X			X
	Remote access to project site			X		
	Better work preparation			X	X	X
	Remote collaboration with teams				X	
	Accurate visualisation of flow of work			X	X	X
	Better assessment and review of performance					X
	Reducing variability		X			X
PEOPLE	Ownership of information	X				X
	Rich participation	X			X	
	Sense of appreciation	X				X
	Common understanding of project			X	X	X
	Builds more trust, Reduces blame culture	X	X			
	Selfless sharing of information	X	X		X	
	Reduces Assumptions, Clear decision making		X	X		X
	Overcoming barriers of physical interaction	X		X	X	X
	Willingness to improve		X			X
	RESULTS ACHIEVED ON THIS PROJECT	**Single source of truth Information Transparency**	**Mistake Proofing**	**Visualisation**	**Integration**	**Collaboration Performance Improvement**

DISCUSSION

It is evident from the case study that the team deployed ICT towards streamlining construction project delivery by taking ownership of work, resolving clashes between work packages, and taking control over the risks posed by the project environment. However, it is important to note that the success is evidently credited to the adoption of the new processes offered by the technology, thereby marking a cultural shift. Some of the key points of discussion from the case study are listed below.

- **ICT enables trust and collaboration in the team:** A common platform enriched by information removes the barriers to communication and helps build an environment of trust and support. This is essential for teams to come together towards problem solving, rather than pushing the problem across one-another. While tools promise collaboration, it is important to understand that while technology does enable collaboration, it does so through the provision of accurate information that helps build the collaborative environment.
- **Renewing Processes is Key**: Adding technology on existing processes that haven't proven beneficial will just bring the processes to failure point a lot faster. ICT cannot do improvement on its own unless we allow the new technology to create new processes. With the right alignment of new tools with new processes, the team can enable an environment of least resistance to focus on driving efficiency in project delivery, rather than focusing on overcoming cultural resistance towards the new technology.
- **Technology is not a direct Solution:** Adoption of any new technology does not guarantee success unless the people are ready to make a cultural shift in their work processes. The key to enabling efficiency through ICT is the richness and accuracy of the information provided, the simplicity of its dissemination across the project team, and the ease of contributing to it. All these factors collectively contribute to define processes that support the technology adopted towards its full utilisation that finally helps to improve project delivery workflows.

While all three aspects are interconnected, interdependent, and equally important, the industry has struggled to integrate these effectively since decades. While it might not be a one-size-fits-all, a framework of this manner has the capability to offer the first steps towards understanding the nuances of these three aspects to then build on further.

CONCLUSION

The construction industry continues to be plagued by major challenges stemming from inefficiencies in its core processes. A significant credit for scope of improvement is given to the implementation of ICT in the industry. However, the notion of plugging in a tool and expecting improvement in overall productivity and benefits to the project and the team has proven to be a narrow perception in the industry. Previous research reinforces the drawbacks of this perception and necessitates the implementation of a holistic approach to streamlining construction project delivery.

This research addresses the misalignment of the three core organizational aspects of construction - ICT, process, and people, by proposing a framework of their interaction. Building on their observations and experience on the case study project, the authors map the interaction between the tools deployed and the value impact on the processes and team culture to highlight their complex interdependency.

The interaction matrix can be applied and referenced on other projects to further explore the value proposition from project processes and culture with the adoption of new tools and

technology. The interaction matrix depicts how the three aspects function in sync with each other to achieve specific results that can help drive project performance.

LIMITATIONS

The authors acknowledge that the framework is built from a specific case study where limited tools under the ICT umbrella have been deployed with select participants and a set of value propositions have been studied. However, the authors would like to reiterate that this framework is built as a starting point for fellow researchers from the scientific community as well as industry practitioners to further contribute their observations and learnings to. This will help build the framework with more tools, more value propositions, and feedback from their teams to make it more effective and useful for the wider community in the construction industry.

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