INFORMATION MANAGEMENT USING INFORMATION AND COMMUNICATION TECHNOLOGIES FOR PERFORMANCE IMPROVEMENT ON CONSTRUCTION SITES

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THESIS ACCEPTANCE CERTIFICATE

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ABSTRACT

Construction projects are generally information-intensive, entailing multiple stakeholders at different phases. Efficient project delivery and performance heavily relies on the inter-stakeholder relations that relies on proper information management (IM). Nonetheless, the current practices in Pakistan's construction industry do not provide a viable environment for timely information access and sharing among stakeholders. The lack of implementation of information and communication technologies (ICTs) for IM remains one of prime factors in project delay, cost overrun and reworks on most projects. This study conducted a survey with 180 construction industry professionals, which revealed the sector-wise state of affairs of IM at construction sites in Pakistan, including the awareness about modern ICT tools and barriers to their adoption. It has also identified the key performance indicators required in ICTs for improving construction information management resulting in better communication and coordination among stakeholders. An IM framework is also proposed to facilitate ICT adoption based on the construction sector by overcoming the barriers through need assessment and increasing awareness. This research strives to standardize the management of project's internal and external communication and give access to real-time information for improving the overall project performance.

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List of Acronyms

- CI Construction Industry
- IM Information Management
- ICT Information and Communication Technology

- ACI American Concrete Institute
- AEC Architecture, Engineering and Construciton
- AIDC Automated Identification and Data Capture Technologies
- BIM Building Information Modelling
- CAD Computer-Aided Design
- CC Cloud Computing
- DBMS Database Management System
- EDM Electronic Document Management
- EDMS Electronic Document Management System
- GIS Geographic Information System
- GPS Global Positioning System
- HRM Human Resource Management
- IDI ICT Development Index
- ITU International Telecommunication Union
- LADAR Laser Detection and Ranging
- OM Organizational Memory
- PEC Pakistan Engineering Council
- PMIS Project Management Information System
- RFI Request for Inspection
- RFID Radio Frequency Identification
- ROI Return on Investment
- SMEs Small and Medium Enterprises
- TCP/IP Transmission Control Protocol/Internet Protocol
- WMS Workflow Management Systems

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Chapter - 1

INTRODUCTION

1.1. Study Background

Construction projects are information intensive and characterized by diverse and scattered information such as working drawings, measurement sheets, cost analysis charts, risk registers, progress reports, etc. (Mbazor & Adedayo, 2018). They also entail multiple stakeholders at multiple phases of the project lifecycle, whose inter-relations rest, inter alia, on proper information flow and exchange. Consequently, the project success is inextricably linked to continuous and ordered information management (IM) for efficient project delivery and performance (Aziz, et al., 2016). However, the eight components of IM (objectives, inputs, processes, outputs, resources, practices, people, and constraints) (Aziz, et al., 2016) lack focus, and the non-application of modern information and communication technologies (ICTs) is one of prime factors in project delay, cost overrun and reworks on most projects (Demian & Walters, 2014). Therefore, a meticulous effort is necessitated in project information management in monitoring and controlling the projects as well as to increase their efficiency and performance (Shahi, et al., 2014).

The accurate acquisition, storage, transfer, accessibility, and integration of information in construction processes is vital for achieving pre-defined project objectives through collaboration and coordination (Al-Maatouk & Othman, 2018). Research has nevertheless inferred that IM in construction industry still takes place manually (Demian & Walters, 2014). Despite the emergence of new technologies, e-mails remain the popular medium for exchange of informaiton (Demian & Walters, 2014). The current practices do not provide a viable environment to meet the information access and sharing requirements among stakeholders, especially between the design and site teams (Al-Maatouk & Othman, 2018). In a nutshell, review of construction operations reveal a much needed upgradation of process management (Viljamaa & Peltomaa, 2014).

This study aims to deliver productivity and performance gains (resource efficiency, cost-effectiveness, and scheduled completion) by standardizing the creation, collection, revision, storage, and transfer of information through electronic workflow processes. The research will look upon the existing scenario of construction processes in Pakistan with regard to information management, and provide improved construction control through better communication and coordination among stakeholders using the modern scientific tools.

1.2. Problem Statement

- Despite the widespread increase in digitization, paper based information flow remains prevalent in construction industry causing low productivity and excessive operational costs
- Construction industry lags in terms of adoption of modern ICTs for information management, resulting in delays that lead to claims and disputes
- Currently, the information management plan is provided in bidding documents, but stakeholders hardly comply with it in letter and spirit: adoption of ICTs remains undervalued and overlooked

1.3. Research Objectives

- To determine existing information management practices and challenges to adoption of ICTs in the construction industry.
- To identify the requirements and key performance indicators (KPIs) for effective information management practices
- To develop information management framework facilitating collaboration among stakeholders for productivity and performance improvement for the construction industry

1.4. Research Significance

Timely information and communication aids in on time project completion with less cost and better quality (Khan, et al., 2016). Currently employed construction management tools like Procore, Aconex, help to organize workflow, keep track of work progress, and manage labour hours; however, these tools are supported on manual, subjective and erroneous, inputs. Moreover, many Small and Medium Enterprises (SMEs) do not even consider using these or other related tools.

Such framework is required which incorporates the latest tools in construction industry that offer site management in creating and communicating drawings, models, progress plans, safety information, and progress reports at the shift end. A central office to be able to remotely manage the execution operations of multiple projects and review the progress and make timely amends, if necessary. Furthermore, it can access real-time information in order to improve processes, report and monitor resources and track progress on a cost and schedule basis to give early insight into productivity and assets. This will increase the productivity, performance and strategic insight, and thereby, increase the profitability.

Improved IM system aims to standardize and unify the project's internal and external information management, will encompass the integrated concept to help engineering and construction firms reduce information transfer barriers, become more productive, and improve their overall performance.

1.5. Advantages

The study will provide following benefits to the construction industry and enhance management of construction projects through modern information management framework:

a. Proper acquisition, storage, sharing and accessibility of information.
b. Integration, collaboration and coordination among stakeholders
c. Timely and pertinent communication between project participants at office and on construction sites.
d. Real-time feedback systems from design, planning, and execution teams.

Specifically, IM framework will ensure the following:

1. Information is entered once and not duplicated, and managed through systems like Electronic Document Management System (EDMS). Plans are distributed in electronic forms, and not uses time-consuming and laborious manual work. (Bormann, et al., 2009).
2. Information is integrated with a planning and scheduling software, like a Database Management System (DBMS), for progress reporting and corrective decision making.
3. Real-time data for progress tracking and monitoring and integration of Project Management processes.
4. Information is presented in a single interface/application and made available project-wide immediately to authorized personnel.

The research will improve the practices of CI in managing information and thereby achieving project objectives within the schedule and budget and at the satisfaction of all stakeholders, without cost overruns and reworks. It will mend the communication gaps, improve remote monitoring of project progress by the parties to contract, and provide real-time information for decision making. It will also aid in assessment and improvement of resource productivity, as well as provide for evaluation of construction and manufacturing processes.

1.6. Scope of Research

The study will be initiated through a literature review process for determining the level of research done on information management for construction industry. Thereafter, questionnaire will be carried out to determine existing information management practices in Pakistan's construction industry. Afterwards, requirements for information management framework will be derived. This information will be utilized for using ICTs in an organized IM framework for achieving the effective collection and distribution of information and provide economical solution to the IM needs. Validity of framework will be conducted by the same construction industry professionals from whom interviews were conducted.

Chapter - 2

LITERATURE REVIEW

2.1. Introduction

The current chapter provides detailed review of literature regarding benefits of information and communication technologies (ICTs). It also discusses the research carried out on adoption of ICTS for information management (IM) in the construction industry. Moreover, it summarizes the earlier efforts to develop ICT based frameworks for information management.

2.2. Construction Industry: Importance and Characteristics

Construction industry (CI) has a significant role in the socio-economic development of any country. It not only provides the livelihood, but also the access to energy, transportation, infrastructure, housing, health and water to a large and diverse classes of society. Pakistan's CI has remained a significant driver in the economic and social uplift of the economy. Economic Survey of Pakistan (2017) reported that contribution of Pakistan's CI was 2.74% in the country's GDP with a growth rate of 9.05%. Country's CI also absorbs 7.31% of labor force directly (Ministry of Finance, 2017), and overall 30-35% of population relies upon CI (Farooqui & Ahmed, 2008). CI's manifold backward and forward linkages with other industries pave the way for country's survival, development, and growth (Farooqui & Ahmed, 2008). Pakistan's construction sector has a great potential role national growth, especially after the inception of China-Pakistan Economic Corridor (CPEC), which is expected to boost the market for the CI. However, the CI remains neglected in Pakistan. The government bodies have failed to make policies and reforms to incorporate the modern practices in the CI. Pakistan Engineering Council (PEC) and the respective ministries have made some strides, but with ineffective implementation. Nevertheless, to satisfy the national needs, CI needs an efficient and proactive management of projects to increase the performance and hence the profitability.

2.3. Information Management

2.3.1. Data and Information

Data and information are frequently confused terms. Kelley (2002) distinguishes between the two as follows: Data comprises the plain, unrefined, and generally unfiltered information; whereas, information is the processed data which has evolved to the point of being valuable for analysis and decision-making. Liev (2007) asserts that information contains meaning, implication, or input for decision and/or action. Information is thus the meaningful form of data, which is used in the understanding, learning and modifying of the user experience and practices.

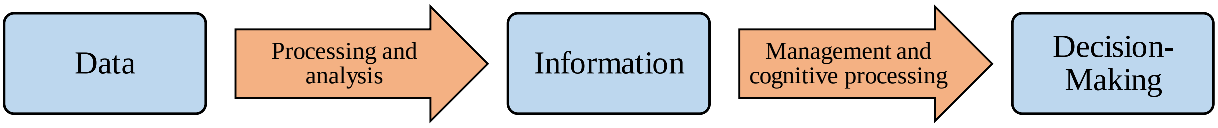

Figure 1: Relationship between data and information

2.3.2. Information Management

Detlor (2010) defines information management (IM) as the management of the processes and systems that create, acquire, organize, store, distribute, and use information, with the goal to help people and organizations access, process and use information efficiently and effectively. Liev (2007) states that IM includes reconstructing a picture of historical events, collecting intelligence, projecting or forecasting possible future events, planning for different developments, and carrying analysis for decision making and/or problem solving. Hence, predicting, undertaking, and reviewing the actions of various entities.

Six distinct IM processes are identified by Choo (2002), which are shown in Figure 2.

Figure 2: Six information management processes

Information is not for leaving idle but is subject to manipulation and changes as new information is acquired (Winn, 2003). Moreover, the information stored in memory needs to be accessible in-time for effective recall and retrieval (Lee & Kim, 2018).

2.3.3. Information Management and Project Performance

Project execution performance is significantly enhanced by the management of the three information variables: quality, quantity, and timing. Real time acquisition and distribution of quality information is paramount in swift identification of cost, quality and schedule discrepancies in project execution and timely decision making for making apt response to disputes and nonconformities (Ahuja, et al., 2009). At organizational level, information management (IM) supports organizations function advantageously and competitively, and assists people better accomplish their tasks and become better informed (Detlor, 2010).

IM is therefore a strategic advantage w.r.t four different advantages (Choo, 2002): (i) cost-reduction (ii) risk-reduction (iii) value-addition, and (iv) value-creation through the information-based products and services. IM also supports the contractual bridge between the assorted stakeholders involved in a project: it manages the connectivity, keeps the parties updated, and ensures project reporting and planning (Senaratne & Ruwanpura, 2016).

2.4. Information Management in Construction Industry

Construction Industry (CI) is an information-intensive industry: it requires continuous coordination and collaboration among a substantial number of specific but mutually dependent contracting parties. Early and reliable information is an essential ingredient for effective collaboration (Azhar, et al., 2014); nevertheless, CI has not exploited this success factor efficaciously.

CI is challenged with various information exchange problems in information-sharing with stakeholders (Voordijk & Adriaanse, 2016). Presently used methods at construction sites are more retrospective and reactive, and these tend to solve problems and not focus on prevention. On the other hand, proactive approaches collect information proactively to monitor and control the construction performance (Gao , et al., 2012). Other problems associated with current construction practices (Gao , et al., 2012) include: (1) Limited information about recurring uncertainties, (2) Absence of a defined strategy for information needs and their collection, and (3) Ad hoc decisions on selection and adoption of information technologies.

CI has also come to a deduction from its experiences that manual book-keeping is laborious and time-wasting (Demian & Walters, 2014). Meanwhile, CI lagged in the adoption of ICTs at the field level. Senaratne & Ruwanpura (2016) analyzed that only a few previous studies undertake project communication management for construction sector. Tsai, et al. (2007) have indicated numerous asynchronous operations with redundant sub-processes adversely affect information acquisition, storage, and distribution. The implementation of information management (IM) tools, with the exception of mobile phones and e-mail, has remained deficient in CI (Solis, et al., 2015). Field personnel lack the skill set to adopt the state-of-the-art tools in their work practices and gain the manifold untapped benefits of these tools (Solis, et al., 2015).

2.5. Information Management Practices: Need and Importance

The diverse and voluminous information at construction sites need careful consideration in the acquisition, processing, and distribution to stakeholders. Following are the construction management processes which are significantly improved by the efficient information management:

2.5.1. Inspection

Routine inspection in essence assures that the quality and compliance are achieved in the progress of works. Inspection reports need prompt distribution to the owner, designers, contractors, subcontractors, suppliers, and the building officials to allow timely identification of compliance or the need for any corrective measures (ACI 318, 2014). Inspections may be carried out for determining status and quality of works, valuation for interim payments, mock ups and samples, commissioning, defect rectification, completion, and handing over.

Traditionally, Request for Inspection (RFI) forms are used at the sites and are communicated to client weekly or monthly through the log book. Other visual observations at site are either recorded in site-visit log, or merely verbally told to site supervisor. These are the subjective and ineffectual ways of acquiring the information-at-site, interpreting in the office and communicating to the others for erroneous re-interpretation later on.

2.5.2. Progress Reporting:

Project status reports are a regular process to compare the progress planned and progress achieved. Scheduled progress reports are submitted daily, weekly, monthly, quarterly and are a major component for effective project management which let timely decision making and remedial action (Golparvar-Fard, et al., 2009). Good and factual reporting covers details about costs, schedule, resources, risks, safety, progress, and quality (Martinez-Rojas, et al., 2015) and, therefore, safeguards against unexpected surprises to client, keeping the project stakeholders informed about the critical forthcoming issues.

Progress reports are normally generated in the design office based on the manual inspection forms submitted by the site team. The re-entry and manipulation of the data disrupt the authenticity and credibility of the progress report, resulting in various sorts of delays, claims, disputes, and costs.

2.5.3. Material Management

Material management deals with the planning, procurement, delivery, storage and usage of the material resources. For construction project, efficient material management aims to get the right form, quality and quantity of resources (Madhavarao, et al., 2018). Availability of correct real-time data assists in the achievement of optimization of project resources by reducing the wastage and making timely procurements (Ahuja, et al., 2009).

Information Management (IM) equips the contractor to keep up-to-date record of material used and material in store, and allows for proceeding with the procurement schedule and make amends as necessitated (Tsai, et al., 2007). For maintaining timely supply of materials and reducing the cost of projects, a well-planned material management program based on IM is required which improves planning, schedule management, productivity and performance of the project (Madhavarao, et al., 2018).

2.5.4. Document Management

Construction projects involve a plethora of documents, which include contracts, specifications, drawings, schedules, submittals, various sorts of log books, measurement sheets, and payment certificates. The ACI regulation asserts for keeping record of project during the progress of the work and storing it for at least 2 years after project completion (ACI 318, 2014). The management of document and record-keeping serve to keep the stakeholders up-to-date of the status of project and any change orders. It also aids in the solution of claims, disputes and payments.

The current scenario in construction sector is that it employs incoherent mixture of document generation and management where each document is in different format and mostly are inaccessible at site, and changes in the documents are difficult to tract and incorporate. Information Management (IM) and specifically, Electronic Document Management (EDM) technology has the potential to enhance the construction project performance considerably by organizing and integrating the documents to ease the decision-making process throughout the project lifecycle (Martinez-Rojas, et al., 2015). EDM stores documents centrally with general access to every stakeholder and access for making changes to a specific stakeholder. The central repository of documents is based in central office and is accessible by interfaces using specialized browsers (Bjork, 2003).

2.5.5. Defect Management

Defect data refers to the occurrence of specific work conditions and their negative implications. To prevent the defects' reoccurrence, the defect information need to be maintained and communicated before execution of works (Lundkvist, et al., 2014). However, firstly, defect inspections are made to fix mistakes after they have been made and, secondly, most defect data are stored in unstructured ways, like unwritten and simply part of supervisor' memory (Lee, et al., 2016). The information is lost once the supervisor is transferred elsewhere or when the project is over.

The information mangement systems have the potential to draw reliable conclusions from the defect data and identify meaningful patterns of defect occurrence. Lundkvist, et al. (2014) highlighted that proactive information management enhances the quality of projects' defect data and thereby reduce the incidence of defects and improve defect management. Moreover, collecting defect data needs to be standardized through objective and uniform data acquisition techniques which require adoption of information technologies.

2.5.6. As-built information:

The acquisition, organization and processing of as-built information is also of particular significance in the data-intensive construction environment (Abudayyeh & Al-Battaineh, 2003). Keeping records of as-built is cardinal for planning maintenance, rehabilitation, and expansion. At present, the unclear and improper documentation of construction methods, resources, quality control, written and verbal communications, site events, and change orders contribute to misunderstandings, incorrect assessment of project performance, and lack of early warnings (Sepasgozar, et al., 2014).

There is a need to resolve as-built data collection and storage issues and to properly structure as-built information to effectively utilize it in the maintenance and rehabilitation processes (Abudayyeh & Al-Battaineh, 2003). Information Management (IM) maintains as-built information records for tracking progress, analyzing schedule and recording on-site variations (Hegazy & Abdel-Monem, 2012). Automated information systems can generate reports and issue warnings for construction firms to have better control over construction operations and relevant information for decision making (Hegazy & Abdel-Monem, 2012).

2.5.7. Classification of Information

The diverse kinds of information in construction sector need to be synergistically handled (Ciftcioglu, 2003). The classification of information is important for the effective interchange and integration of information among the many roles and phases of industry (Lundkvist, et al., 2014). Classification of information is done through assigning a precise description to each piece of information and stored in a format where searches can be made and information is accessible on time (Ciftcioglu, 2003).

Information technologies can be helpful in storing and assessing information in a particular context for enhanced analysis of construction process while it is in progress (Ciftcioglu, 2003). Optimal delivery of information is ensured to individuals in a right proportion without information redundancy, and resulting in clarity and efficiency.

2.5.8. Workforce Management

Construction projects mostly have a largely fragmented, transient and heterogeneous project-based workforce. The construction industry requires workforce record to be up-to-date with necessary details of the employee: their skill, workhours, and salaries (Wilkinson, et al., 2012). Existing practices, however, present a bleak picture: workforce is extensively outsourced through sub-contracting; recruitment is often reference-based, different works are assigned irrespective of skills and expertise of workforce, salaries are not fixed and paid below the standard rates.

Human resource management (HRM) is critical for overall productivity and cost-effectiveness in the construction industry (Ameh & Daniel, 2017). Information management offers the consistent system of keeping records for HRM processes like recruitment, task-assignment, attendance system, performance assessment, training needs, and retain or retire decisions.

2.5.9. Knowledge Management

Knowledge management is another serious concern in construction sector and is also regarded as one of the key sources for success of construction organizations (Ozorhon, et al., 2014). Since most of data are stored in the memory of project participants and not made part of accessible information systems, the important experiences and valuable knowledge gained from construction projects are lost once the project finishes or the personnel is transferred elsewhere (Martinez-Rojas, et al., 2015). Knowledge, an asset that could help a company in the subsequent projects and avoid recurrence of defects, needs active management and institutionalization for it to be made part of organizational memory (OM) (Ozorhon, et al., 2014).

The systematic integration of knowledge and experiences into the OM has remained a challenge for most of the construction companies. Information technologies develop OM by capturing, organizing, and storing the information from all the project participants including designers, contractors, suppliers, site team, and the owner, and allow the integration of knowledge into the organizational activities. Thus, allowing managerial decisions to be based on factual experiences and reduce the extra time and effort on re-thinking the solution to already solved problems.

2.6. Information and Communication Technologies in Construction Industry

Construction industry is known for its fragmentation, complexity, and multiplicity of participants (Martinez-Rojas, et al., 2015). Vast amounts of data are created, and it's necessary to maintain an integrated repository of information for analysis and decision-making. The timely access to this accurate and up-to-date information is also essential for collaboration among stakeholders (Gao , et al., 2012). Senaratne & Ruwanpura (2016) assert that construction organizations should consider improved project communications to reduce defects and rework. Nevertheless, this access and sharing of information is non-existent among participants who remain unaware of the preceding, parallel, and succeeding construction processes (Ahuja, et al., 2009).

2.6.1. Information and Communication Technologies –An Overview

Information and communication technologies (ICTs) are digital collaboration tools used for collecting and communicating information between participating organizations in a construction project (Adriaanse, et al., 2010). ICTs enable effective and timely communication among project participants and expedite the process of information flow (Azhar, et al., 2014).

With the advancement of information technology, communication and collaboration in projects have become much easier (Brandon, et al., 2005). ICTs provide real time access to information and improve coordination and collaboration between the project team members through improved speed and quality of documents, and resulting in faster communications, decrease in documentation errors, and better financial and schedule control (Ahuja, et al., 2009). ICTs are generally classified into: automated identification and data capture technologies (AIDC), electronic document management systems (EDMS), workflow management systems (WMS), and modelling applications (Brandon, et al., 2005).

1. Automated Identification and Data Capture Technologies

Automated identification and data capture (AIDC) technologies collect and store accurate, complete, and timely field data to control project information flows. AIDC technologies permit organizations to track the progress of construction project, check availability of material supplies and equipment, and to automate the procurement process using bar codes, radio frequency identification detectors (RFID), global positioning system (GPS), laser scanners, and image based scanners, etc.

2. Electronic Document Management Systems

Electronic document management systems (EDMS) are a way to organize and store all the project related documents and drawings in an electronic format using a central database (Bjork, 2003). The database is maintained for latest changes and updates — changes made in this database are automatically communicated to all project participants (Brandon, et al., 2005).

3. Workflow Management Systems

Workflow management systems (WMS) manage the information flow between design and site office, and monitor and record the progress of tasks in construction projects (Shelbourn, et al., 2007). WMS define, administer and coordinate different processes needed for efficient progress of works through a combination of building information modelling (BIM) and automated construction project progress monitoring (ACPPM).

4. Modelling Applications

With the advancement of technologies, computer-aided design (CAD) has evolved into modelling applications, like 3-D, 4-D, and building information modelling (BIM) to support cooperation, coordination, and communication by making a graphical model of a building object (Voordijk & Adriaanse, 2016). These applications expedite the inter-organizational and disciplinary collaboration to enhance the quality and productivity of the design, construction, and maintenance operations in the construction industry.

Despite the above mentioned and many other benefits, the application of ICT tools in a practical context of work is not well understood (Solis, et al., 2015). Nowadays, more and more organizations need to use these technologies in conjunction to achieve synergistic benefits. Questions arise as to which of these technologies meet the business needs most aptly, are more advantageous and profitable, and achieve the return on investment (ROI) in least time period.

The next section provides an in-depth insight to different information and communication technologies (ICTs) with focus on their capabilities and implementation in the project management process.

2.7. Potential Information and Communication Technologies for Information Management in Construction Industry

Information systems are the hardware devices and software packages which allow organizations to process, store, and distribute information to support daily operations and decision making (Martinez-Rojas, et al., 2015). Symons (1991) defines information systems as, "the utilization of computer hardware and software; manual procedures; models for analysis, planning, control and decision making; and a database."

Project management information system (PMIS) has become a necessity for project managers to perform specific tasks, interact with and inform various actors in different organizations and thus promote productivity and performance (Lee & Yu, 2012). The quality of the information system rests on the use of suitable models which acquire information through appropriate tools, represent information in an accessible and user-friendly manner, have large storage with easy retrieval, and use right data analysis techniques to support decision making.

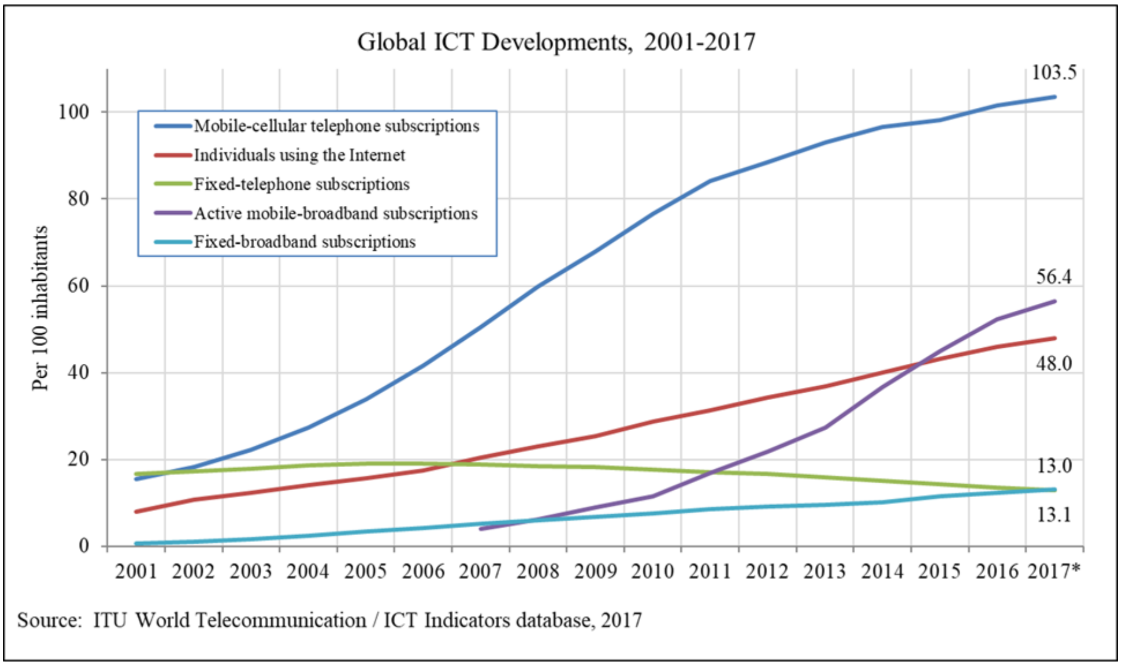

Figure 3: Global ICT Developments, 2001-2017, by International Telecommunication Union

Following is the detailed description of the information system components that can, individually or in combination, achieve the immense cost, schedule and quality excellences for construction organizations:

2.7.1. Internet

Internet is basically a worldwide inter-connected network of computers using standard communication protocols (TCP/IP) for a variety of electronic information flows between the clients and users. It consists of hardware, software and servers to suit the user needs and economy. Internet enables the transmission of text, graphical, audio, video, and live streaming for real-time access to every possible information. E-mail, the most common means of information dissemination, is also based on the internet technology and allows the transfer of project documents including drawings, specifications, and change-orders to be timely delivered to the project participants.

Nowadays, design and management processes are greatly looking forward to internet (web) technology for a suitable platform where management and sharing of construction information is rewarding. Internet has the evident potential of significantly reducing paperwork, postal mails, and time required for information delivery and solving site-design issues (Dawood, et al., 2002).

Internet has actually become a necessity at construction sites, and is regarded as the most economical tool for information sharing in intra- and inter-organizational context. With several advancements in internet component, the speed and quality of information flow has really improved and provides the remote management of construction sites from the head offices (Dawood, et al., 2002).

2.7.2. Cloud Computing Technology

Cloud computing (CC) is "a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction." It basically refers to the on-demand delivery of hosted computing resources. Services available on the cloud range from storage, software, networking, and servers. Cloud may be public, where the services are shared on rent-basis, or private, where it is operated by a single organization having more control of resources.

CC enables communication and exchange of information in an easy, accurate, effective and efficient manner without any geographical constraints for cross-party collaboration

(Zhang, et al., 2017). It has applications in the construction sector for architectural design, structural design, quantity and cost estimation, scheduling, monitoring and control, simulations, and rendering etc. (Kumar & Cheng, 2010). Currently, CC seems expensive to the small-to-medium enterprises (SMEs), for which public cloud is suggested, where they pay only for required services without taking ownership of the services; while for large enterprises, private cloud can handle the software packages and project-specific data and models for distribution among project stakeholders.

2.7.3. Identification and Tracking Technologies

Identification and tracking technologies like barcodes, radio frequency identification (RFID), and global positioning system (GPS), permit automatic data capture for construction processes mainly to track status and movement of resources.

Barcode is an optical, machine-readable, representation of data for the product that carries the barcode. Laser scanners and camera-equipped cellular phone are used to read the barcode and identify the product. RFID uses radio waves of different frequencies to capture and transmit data from a tag, a microchip which stores data and an integrated antenna serving as a transmitter, allowing efficient real-time information visibility and traceability (Lu, et al., 2011). RFID has readers which can be set on any structure in the reading range and each reader can scan multiple tags at a given time. GPS locators

These are mainly used in construction supply chain management but also perform other operations like automated acquisition of information pertaining to contract documents, drawings, progress reports, quality test reports, and personnel identification, especially when the project participants are geographically separated.

2.7.4. Vision and Laser Technologies

Photographic data has become the favored documentation medium, as it contains rich information (geometry and appearance), and data are collected quickly and inexpensively. Vision technologies and laser technologies are thus applied in tracking in large-scale, congested sites. Laser scanner, also known as laser detection and ranging (LADAR), is very popular for construction applications because it can capture very accurate 3D data for an entire construction site, using only a few scans, and to generate as-built models (Lee & Kim, 2018). The high-resolution digital cameras, extensive data storage capacities, and the availability of internet connections on construction sites have enabled capturing and transmitting information about construction performance on a massive scale.

Laser technologies also offers quality management, where laser scanners have been applied for defect detection and embedded sensors (e.g., temperature and pressure sensors) are used to monitor the quality of materials. The use of these kind of technologies offer timely and accurate monitoring of on-site construction operations. This monitoring can bring an immediate awareness on project-specific issues and the collected data provide practitioners with the information they need to easily and quickly make project control decisions.

2.7.5. Geographic Information System

Geographic Information System (GIS) is among the most widely embraced software technologies of the past decade. GIS consists of organization of computer hardware, software, user, and geographic information. User is able to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information, including the spatial and attributes information, which are synchronized, so that both can be queried, analyzed, and displayed (Martinez-Rojas, et al., 2015).

This synchronous management of different pieces of information make the construction project management successful by aiding in design and pre-construction planning, providing the reports of project progress status, material delivery, and location of allied facilities. GIS finds most utility in the construction of roads, electric cables, pipelines, and bridges.

2.8. Adoption of Information and Communication Technologies in Construction Industry

Project-specific settings turns construction information management very complex as the fragmented project teams come together with different values and interests to a construction project (Martinez-Rojas, et al., 2015). Presently, the communication issues among team members often result in project delays, expensive reworking and building defects; and the project managers frequently fail in change management (Zhang, et al., 2017). Meanwhile, current reporting formats (textual reports, progress curves, and photographs) communicate project progress neither effectively nor quickly. Information and communication technology (ICT) tools provide solution to these difficulties. However, construction industry has been slow in adopting ICT, and often available and easily accessible technology is not being utilized to the full extent. This is reflected both in the literature and practice.

The construction industry is well-known as a fragmented and dynamic sector due to the subcontracting system. The contractually-driven relationships in construction sometimes bring a lack of mutual respect and trust as the result of ineffective communication. In the process of communication, information must be transmitted to the receiver without misunderstanding or confusion (Lee & Kim, 2018). The project information management tools and techniques are not used in high frequency among stakeholders/owners. Essential information related to the project is not disbursed timely to them resulting in unnecessary costs to the contractor

The distorted and misunderstood information may lead to costly problems during Construction. The purpose of this paper is to establish a conceptual framework for effective communication in the construction management domain (Lee & Kim, 2018). Ineffective communication may result in misunderstandings, delays, and defects in many constructed works.

2.8.1. Case of Developed World

Although the use of electronic devices, automated identification and data capture systems, and the networking to abridge information generation and distribution has become a conventional means of on-site information management, the study (Dawood, et al., 2002) demonstrated that inadequate communication and incorrect information still adversely influence progress control and project management. The use of ICTs in CI is still lackluster and not as effective and efficient as envisioned (Miettinen & Paavola, 2014). Unfortunately, most of the important data are exchanged in unstructured text documents, increasing the complexity level for data retrieval, poor interoperability between different management systems, and harder information reuse (Martinez-Rojas, et al., 2015).

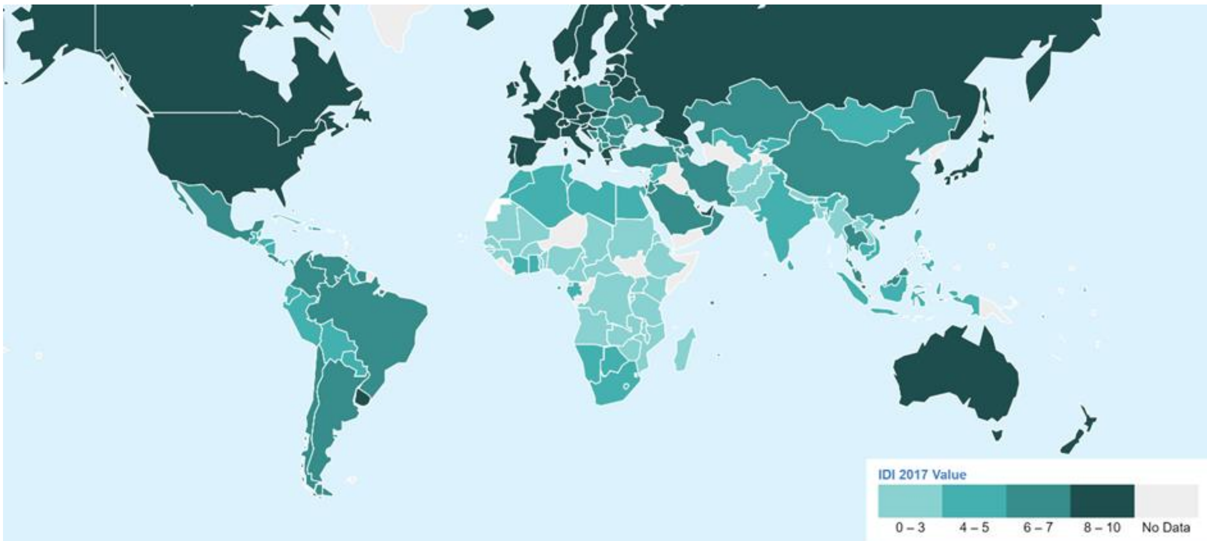

Figure 4: ICT Development Index (IDI) Report by International Telecommunication Union

2.8.2. Case of Developing World

Developing countries in general and Pakistan in particular have been slow to take advantage of information and communication technology (ICT) in construction industry. ICT Development Index, 2017, ranks Pakistan 148 out of 176 countries in the world (International Telecommunication Union, 2017). The prevailing project practices are mostly out-of-date. The computer aided tools and techniques are used only in preconstruction and construction stages, but still not within acceptable range. There lie notable project management errors owing to improper information management, and resulting in lack of communication, lack of competent project control, and slow and opinionated decision-making. exist (Farooqui & Ahmed, 2008). Given that technology is instrumental in project performance, this calls for an immediate implementation of state-of-the-art ICT tools that have been implemented in the developed world (Farooqui & Ahmed, 2008). However, this requires a cultural and behavioral shift in the mind-set of all project participants notably top management in order to increase CI's performance and competitiveness (Farooqui & Ahmed, 2008).

To enhance the coordination, teamwork, productivity and industry performance significantly, the need of the hour is that construction organizations of developed and developing world should realize the potential of ICT and re-engineer the project management protocols, and implement international standards of reporting and information management.

2.9. Challenges to Information Management

ICT fosters enhanced communication, which is a prerequisite for effective collaboration, coordination and data exchange among project participants (Azhar, et al., 2014). The construction industry (CI) may be aiming to adopt the latest information and communication technologies (ICT), but there exists challenges (Martinez-Rojas, et al., 2015) which need to be addressed. From the literature review of 15 publications in well-known journals, following 25 barriers to ICTs adoption have been identified:

1. Resistance towards new technology
2. Lack of knowledge about ICTs
3. Lack of adequate infrastructure
4. High operating and upgradation costs
5. Lack of concern by senior management
6. High initial capital costs
7. Inconsistent use by the employees

8. Multiple entities working on one project
9. Information form variation
10. Lack of standard practices
11. Data authorization concerns of organizations
12. Limited budget of organizations
13. Project delay due to ICTs delivery to project site
14. Electricity disruption issues
15. Lack of knowledge about returns on investment
16. Type of construction project
17. Absence of incentives in contracts
18. Lack of skill-set to manage ICTs
19. Temporary nature of construction projects
20. Additional literacy required to interpret ICTs output
21. Lack of information management strategy
22. Data privacy concerns of organizations
23. Trust issues with ICTs information delivery
24. Poor coordination among different organizations
25. Type of organization

Collaboration is not achievable without the use of ICTs (Shelbourn, et al., 2007). Effective implementation of ICT tools for construction management requires requires consensual adoption of these tools among organizations; which is nevertheless, not given much regard (Ahuja, et al., 2009).

2.10. Addressing the Challenges to Information Management

Information and communication technologies (ICT) not only aid in organizing, storing, analyzing and retrieving information but also in sharing information in an organization in all the directions, i.e. upward, downward and laterally. Proactive management of projects requires gathering information about activities that have not started yet, and increasing the capability of accurately capturing the complete information in a cost effective manner (Gao , et al., 2012).

The research (Tsai, et al., 2007; Voordijk & Adriaanse, 2016) identify following elements for an efficient information system;

- Efficient on-site data capture

- Reduced sub-operations for information generation
- Reduced time-consuming manual paperwork
- Efficient translation and communication of information to project participants
- Economic and uniform implementation
- Collaboration between academia, industry, and government agencies to address the operational, legal, privacy, and economic concerns.

The criteria for an efficient IM framework have been outlined in literature and overall, following 25 requirements have been recognized:

1. Less technical maintenance
2. Economical and profitable
3. Improves competitive advantage
4. Personal motivation for adoption of ICTs
5. Promoting standard working practices
6. Long service life
7. Ensures data security
8. Efficient on-site data capture
9. Efficient communication with project participants
10. Reduced clerical staff
11. Reduced manual paperwork
12. Convenient information access
13. Reduced number of sub-operations
14. Recognition by the stakeholders
15. Enables virtual meetings and networking
16. Enables multi-tasking
17. Simple and user-friendly
18. Improves speed of communication
19. Eliminates data fabrication/modification issues
20. Adaptability to project environment
21. Promotes business strategy
22. Intra- and inter-organizational integration
23. Compatibility with construction ecosystem
24. Workable irrespective of firm size
25. Promotes coordination in site operations

2.11. Information and Communication Technologies Investment Decisions

Construction industry is among the lowest innovation industry among others; it has limited capital which needs to be invested after carefully scrutinizing all costs and benefits (Lee & Kim, 2018). Investment must be based on the potential of higher profits, reduced costs, value creation, value addition, stakeholder satisfaction; in short, improvement in project performance and profitability. Making justification for investment in information and communication technologies (ICTs) is, however, complex and requires diligent deliberations as direct and indirect outcomes of ICTs are difficult to enlist and quantify (Ruddock, 2006).

Different ICTs have different capital expenditures (CapEx) and operational expenditures (OpEx) that arise during the construction project lifecycle. CapEx refers to the money a company spends towards assets for their purchase and upgradation; while OpEx are the expenses to run the day-to-day operations. These can be calculated from the retail prices of specific ICTs and their running expenses.

On the other hand, there are benefits that are reaped from ICT investment. These include tangible and intangible benefits. Tangible benefits refer to direct reduction in costs of managing information and improvement in manpower productivity and project performance with respect to delivery of works. Intangible benefits include the stakeholder satisfaction, organizational reputation, and project impact on the competitors and prospective new clients.

2.11.1. Evaluating Investment Decisions on Information and Communication Technologies for Construction Industry

Assessment of ICT investments and difficulty of identifying specific ICT cost benefits is challenging. High initial costs associated with information and communication technologies (ICTs) deters most of the enterprise managers from adopting these technologies, even if later on, they have to employ more manpower, perform many reworks and work beyond planned schedule (Ruddock, 2006). The benefits from the investment are many a time not paid due regard i.e. neither enumerated nor quantified, resulting in following conventional and laborious techniques of information management. Thus, construction professionals need a way of properly weighing the pros and cons of the ICT investment to achieve higher productivity and profitability.

Anderson (2000) reviewed thirty different evaluation methods for ICT investments; nevertheless he did not find any single technique to be consistent. Dehlin and Olofsson (2008) described methods for evaluating ICT investments as: Cost Benefit Analysis (CBA), Discounted Cash Flow (DCF), Net Present Value (NPV), Internal Rate of Return (IRR), and Return on Investment (ROI). All these methods complement the investment decision and make forecasts realistic. Return on Investment (ROI) measures the effectiveness of utilization of business capital in generating profits: higher the ROI, higher the profit (Dehlin & Olofsson, 2008).

2.11.2. Assessing Returns on Investment of Adopting Information and Communication Technologies for Information Management

Return on Investment (ROI), 'Rate of Return' or 'Return on Capital Employed', compares the potential benefits arising throughout the project lifecycle from an investment to its costs accrued. Feibel (2003) described the ROI as the ratio of net gains and cost of investment:

$$\text{ROI (\%)} = \frac{Gain\ from\ investment - Cost\ of\ investment}{Cost\ of\ investment}\ x\ 100$$

Giel and Issa (2013), after highlighting the absence of a standard method for calculating return on investment in construction sector, presented ROI Estimation Model for Building Information Modeling. They noted the tangible and intangible benefits in terms of savings against the direct and indirect costs of investment, and the resulting ROIs of six case studies ranged between 16% – 1650%, which are presented in Table 1. High ROIs were achieved where the BIM was fully incorporated and integration with project management processes.

Table 0-1: Returns on Investment by** (Giel & Issa, 2013) **for BIM Adoption in Construction Projects

S.No.	Project ID	Total Costs ($)	Total Benefits ($)	Return on Investment (%)
1.	A	35,640	48,723	36.70
2.	B	44,220	51,365	16.20
3.	C	53,510	254,635	376.00
4.	D	58,995	123,330	109.00
5.	E	208,788	3,662,009	1,653.90
6.	F	222,000	887,700	299.90
	Average ROI =			**415.00**

Marsh and Falanagan (2000) provided in their research metrics by which ICTs influence the construction processes: operation and management. They studied the capital costs and recurring expenses of high-density bar codes; along with the measurement of benefits. Dehlin and Olofsson (2008) in their ICT Investment Evaluation Model identified several cost and benefit variables for Virtual Reality (VR) adoption in the project design and execution. They concluded that evaluation of ICT evaluation techniques involve several complementary strategies for investment decision to be realistic and profitable.

Chapter - 3

RESEARCH METHODOLOGY

3.1. Introduction

This chapter provides an understanding into the multi-stage applied research undertaken for the study and development of information management (IM) framework using information and communication technologies (ICTs) for performance improvement of construction projects in Pakistan. It will describe the utilization of literature and other research tools to meet the research objectives and foster the basis and effectiveness of information management framework.

3.2. Research Design

The general plan for addressing the research questions is known as research design (Saunders , et al., 2009). It involves deciding among research strategies for data collection and analysis, validation and output of results. It is a roadmap which guides the researchers throughout for completion of the research programme.

Before proceeding to research design for this study, the research objectives are reproduced here;

1. To determine existing information management practices and challenges to ICT adoption in the construction industry
2. To identify the requirements and key performance indicators (KPIs) for effective information management practices
3. To develop information management framework facilitating collaboration among stakeholders for productivity and performance improvement for the construction industry

The research begins with a review of literature for analyzing the status of research done on information management (IM) in construction industry. Literature review presents the description of information management tools applicable to CI and their applications. It also underscores the numerous benefits provided by integration of information and communication technologies (ICTs) in information management in terms of economy, quality, and performance. Afterwards, the research objectives are targeted using the appropriate techniques, where the selection of technique is determined by the relationship among the research objective, type of data and analysis required on the data.

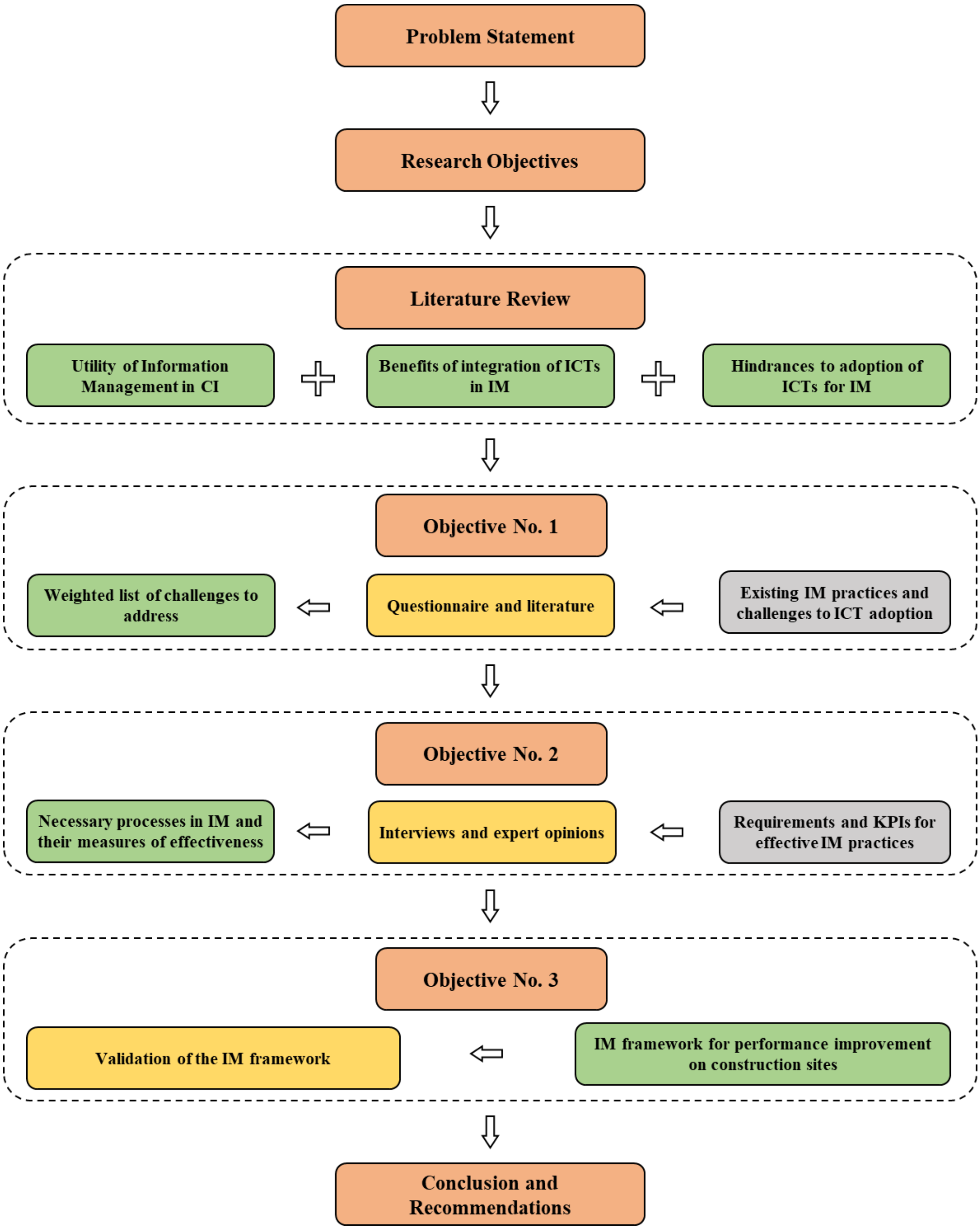

Figure 5: Flowchart of the Research Design

3.2.1. To determine existing information management practices and challenges to ICT adoption in the construction industry

A questionnaire asks the construction industry personnel, including the contractors, site engineers, construction managers, project managers, and project developers, about their existing information management (IM) practices as well as their awareness of ICTs and the economic and performance gains pertaining to those ICTs. Construction professionals rank challenges to information management and adoption of ICTs in Pakistan's construction industry. Output will be a weighted list of challenges which need to be overcome by the realization of benefits of ICTs and/or contractual obligations. This environmental scan encompasses the primary assessment of barriers and enablers for ICT based information management.

3.2.2. To identify the requirements and key performance indicators (KPIs) for effective information management practices

Literature, interviews, and expert opinions will be utilized for chalking out the possible solutions to information management and overcoming the ICT adoption challenges. This will help in identifying the requirements and key performance indicators (KPIs) for an effective information management. The criteria for selection and organizing ICTs in the framework will be based on the KPIs for achieving practicable and economical information management and hence project participants' collaboration.

3.2.3. To develop information management framework facilitating collaboration among stakeholders for productivity and performance improvement for the construction industry

Considering the industry needs and the most economical solutions to cater the requirements of information managements, a framework will be proposed. This framework will utilize ICTs with shorter breakeven periods and higher returns on investment (ROI), so that the stakeholders feel satisfied by the implementation of IM framework and obligated to adopt it in their construction projects. Furthermore, the developed framework will be validated. The framework will be studied to examine whether the construction industry requirements are met satisfactorily.

Thus, the crux of research is to analyze the need, adoption and potential gains from the effective information management through information and communication technologies in Pakistan's construction sector.

3.3. Survey Questionnaire

The research aimed to determine the information management (IM) practices of construction sites and provide an IM framework for facilitating coordination and collaboration among stakeholders; in this regard, a comprehensive field survey was essential. This survey was carried out using the questionnaire which collected responses from the contractors, site engineers, construction managers and project developers in the construction industry of Pakistan. The questionnaire elicited responses in following four sections:

- Existing information management (IM) practices
- Barriers to adoption of modern information and communication technologies (ICTs)
- Requirements for effective information management practices
- Ranking the most useful ICTs for construction sites.

After a brief respondent profile, study pertinent questions ensued, which included 51 five-point Likert Scales inquiries. Firstly, it asked the respondents about their level of awareness and proficiency in different ICTs. Secondly, it inquired them the frequency of usage of ICTs in various construction management processes and their level of satisfaction with present IM practices were asked. This was succeeded by asking respondents to assign weight to the most significant barriers to the adoption of ICTs and to the most important requirement in the ICTs for its adoption on construction sites.

Chapter - 4

RESULTS AND DISCUSSION

4.1. Introduction

Proper Information Management (IM) keeps the wheels of collaboration turning and leads to improved stakeholder coordination in construction projects. However, the tools to improve IM i.e. Information and Communication Technologies (ICTs) though being increasingly developed and employed in other industrial sectors, remain neglected in construction industry. This study aims at increasing the adoption of ICTs on construction sites for maximizing the collaboration and thus the productivity and performance.

The objectives of this research, as set forth in the beginning, encompasses the determination of, in relation to construction projects, the existing information management practices, barriers to adoption of modern ICTs, requirements for adequate functioning of ICTs for construction sites. Moreover, the development of information management framework for collaboration and improvement in productivity and performance is also the agenda of current study.

4.2. Research Methodology

Research methodology for accomplishing the aforementioned objectives is described in the previous chapter. Briefly stating, the following tools and techniques are used in this study:

Literature review and preliminary survey are conducted for the determination of presently in-use ICTs on construction sites. This also yielded the construction sites functions necessitating information management, and the existing role of ICTs in their performance. Afterwards, the questionnaire is developed using Google Forms and responses are collected from the construction site professionals using web-based and actual site visits. The questionnaire is provided with this study as Annexure-A.

The responses are evaluated using statistical tools including MS Excel and SPSS. The reliability, normality and correlation tests are performed using SPSS, and data representation is done in MS Excel. The results of which are presented and discussed in this chapter. Furthermore, the development of information management framework is undertaken considering the construction site needs and functions of different ICTs. This framework is validated by presenting it to experts of construction sites as well as the academicians.

4.2.1 Data Analysis

Through the questionnaire survey, 180 responses were obtained with a suitable mix of different sub-sector experts and with diverse educational qualification, associated organizations and nature of experiences. Before proceeding with drawing inferences from the data, the responses were evaluated using statistical tools including the reliability, consistency and normality tests through IBM SPSS Statistics, and thereafter, data demonstration was carried out using Microsoft Excel.

a. Reliability and Consistency Test - Cronbach's Coefficient Alpha Method

The interpretation of the Cronbach's Alpha value is: data is reliable when value is more than 0.7, data is highly consistent when value is greater than 0.9. The collected data had value of 0.911, i.e. data was reliable as well as highly consistent.

b. Measurement of Normality - Shapiro-Wilk Test

Shapiro-Wilk test evaluates the distribution of data for sample size less than 2000. The test showed that data was not normally distributed as all 51 Likert Scale inquires had significance values less than 0.05, and therefore, non-parametric statistics was used hereafter.

c. Kruskal-Wallis Test

As the data was non-parametric, the data was tested with Kruskal-Wallis test; only 8 out of 51 Likert-Scale inquiries were found with p-value less than 0.05, which describes that client, consultant, contractor, designer, material supplier and academia personnel had differences or dissimilar perceptions about 8 of the total inquiries.

d. Relative Importance Index

The different sections of the questionnaire were analyzed using Relative Importance Index (RII) technique to consider every respondents' feedback towards the inquiries asked in the survey. The technique, RII, analyses the responses to Likert Scale using:

RII = Σ w / A*N, where

w = weights assigned in Likert Scale (for 5-point Likert Scale, w = {1, 2, 3, 4, 5}),

A = highest weight assigned in the scale (for 5-point Likert Scale, A = 5),

N = total number of respondents (i.e. 180 for this study), and

RII ranges between zero to 1.

4.3. Characteristics of Respondents to Questionnaire

The questionnaire was initially circulated on the web using professional networking site LinkedIn among client, contractor, consultant and other related construction professionals. Later on, the site visits were made to reach out to the construction experts.

A total of 180 responses were obtained with a suitable mix of different sub-sector experts with various types of qualification, associated organizations and nature of experiences. The details of the respondents are as follows:

4.3.1. Academic Qualifications

Responses were made by construction professionals having different academic backgrounds. *Figure 6* explains the respondents' highest academic qualification: Construction professionals having professional engineering degree were 81 (45%), with further masters were 88 (48.89%). Moreover, those having doctorate level of engineering education were 8 (4.44%). The construction professionals at senior positions but with only Diploma of Civil Engineering numbered 3 (1.67%) of the total 180 respondents.

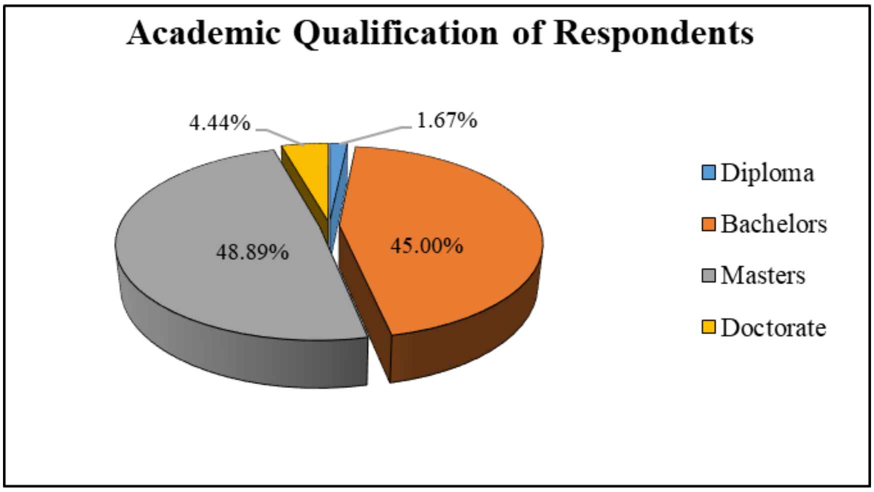

Figure 6: Academic Qualification of Respondents

4.3.2. Professional Experience

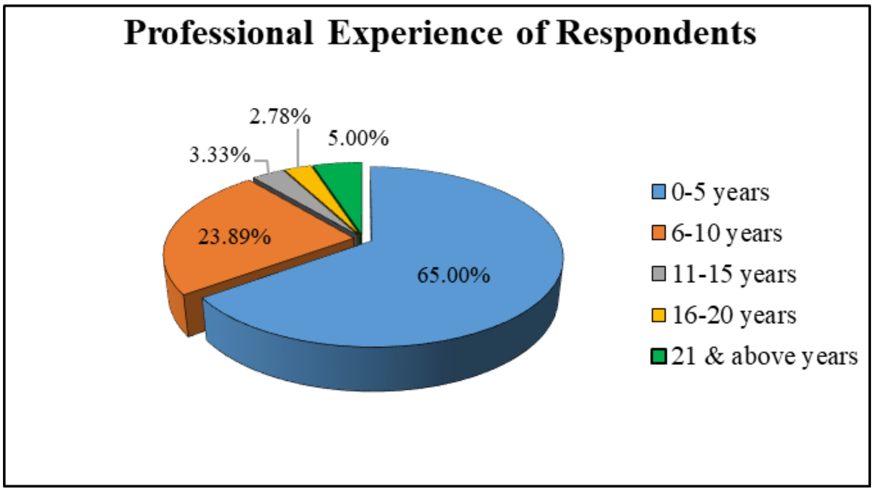

Figure 7: Professional Experience of Respondents

The respondents had varying years of professional experience. Fig. 7 demonstrates that 117 (65%) of respondents carried up to 5 years of experiences, while the next majority 43 (23.89%) had between 6-10 years of experience. Moreover, 3.33% respondents had 11-15 years, 2.78% respondents had 16-20 years, and 5% respondents had more than 20 years of professional experience in the construction industry.

4.3.3. Organization Type

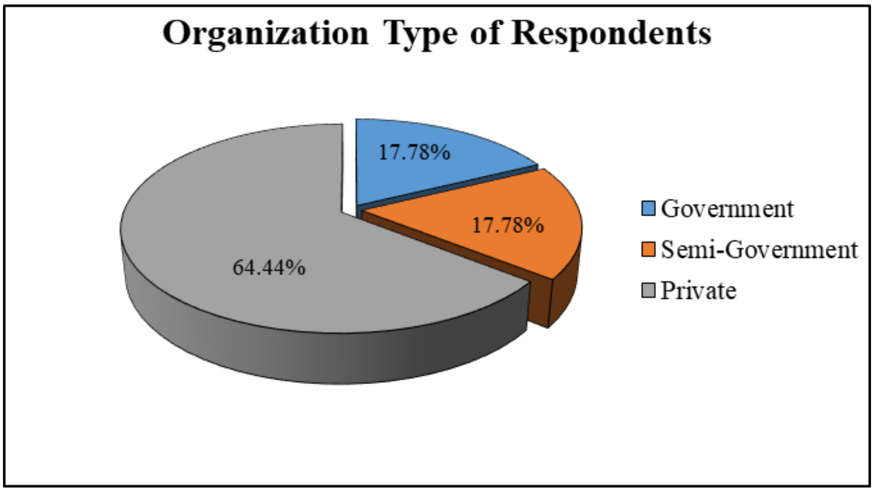

Figure 8: Organization Type of Respondents

Fig. 8 gives the classification of respondents based on their organization type. Out of total 180 construction industry professionals, 32 (17.78%) were from government organizations, with another 32 (17.78%) from the semi-government organizations. Respondents working in private organizations numbered 116 (64.44%) and made the majority of the total respondents.

4.3.4. Organization Role

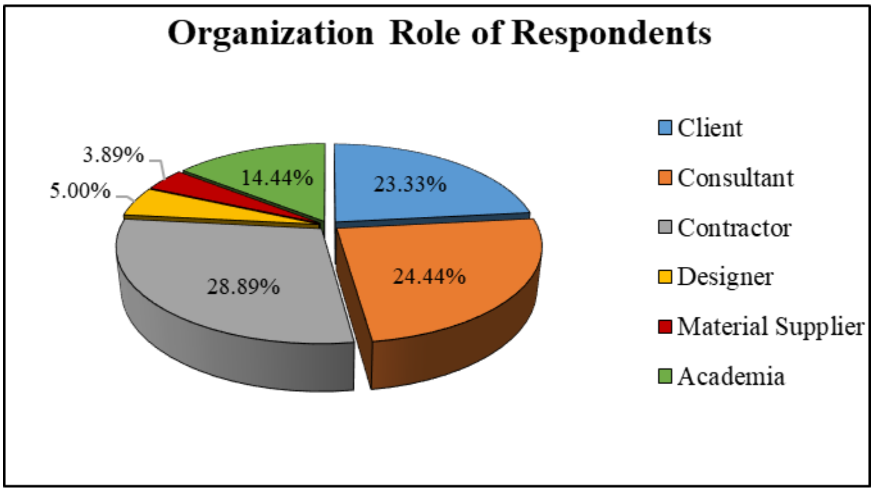

Figure 9: Organization Role of Respondents

Another classification considered for the 180 respondents was their organization's role in the construction industry. Fig 9 shows that 42 (23.33%) respondents belong to client organizations, 44 (24.44%) to consultant, and 52 (28.89%) to contractor organizations. Remaining respondents are designers (5%), material suppliers (3.89%) and academicians (14.44%).

4.4. Awareness and Proficiency in Information and Communication Technologies

This section covers in detail the existing practices of information management (IM), including the professionals' awareness and proficiency about the information and communication technologies (ICTs) as well the functions performed by ICTs on their construction sites, succeeded by their level of satisfaction with their IM practices. The questionnaire responses for this section were evaluated using the technique Relative Importance Index (RII), which is described in the Section 3.2.4.

4.4.1. Hardware

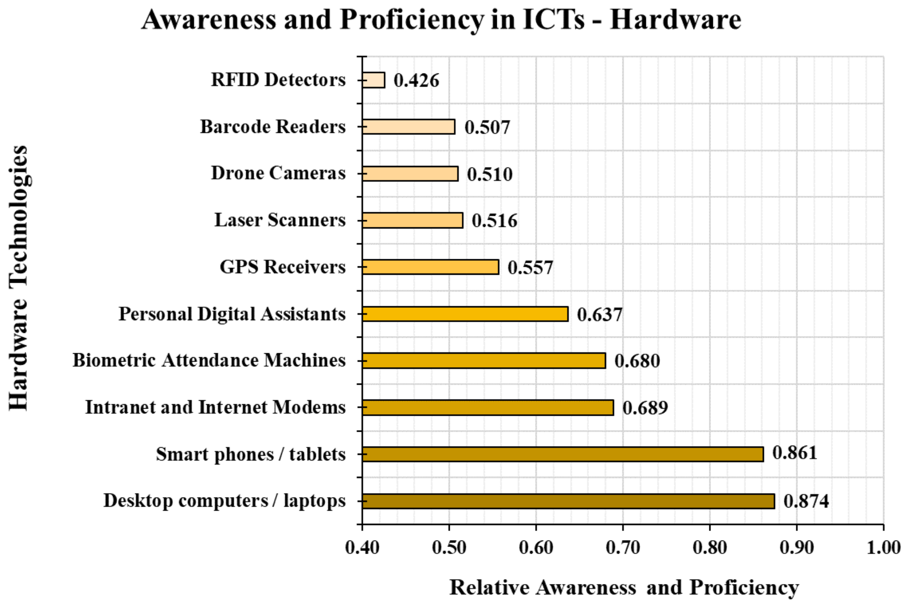

Figure 10: Awareness and Proficiency in ICTs - Hardware

In the case of hardware, respondents showed varying levels of mindfulness about the different ICTs. Fig. 10 demonstrates that desktops/laptops was the most used hardware with RII of 0.874; it was followed by smart phones/tablets with RII of 0.861. Thereon, awareness and proficiency decreases significantly for the hardware. However, respondents are mostly aware of and using the intranet and internet modems, biometric attendance machines and personal digital assistants. Least considered ICTs with RII less than 0.6 are the GPS receivers, laser scanners, drone cameras, barcode readers and RFID detectors.

4.4.2. Software

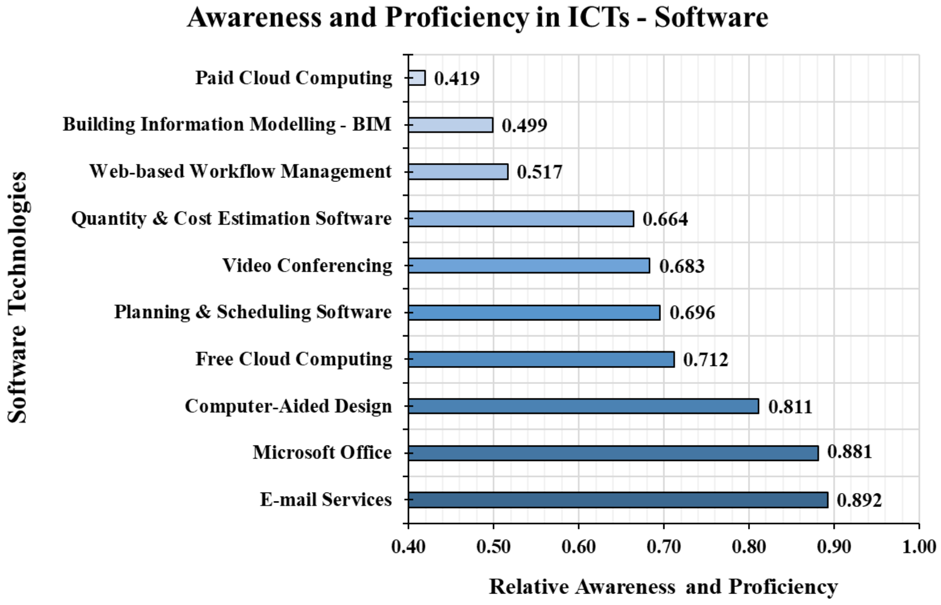

Figure 11: Awareness and Proficiency in ICTs - Software

For software applications, respondents showed a gradual decrease in awareness and usage from e-mail services towards the paid cloud computing. Fig 11 establishes that e-mail services remained the favourite utility with RII of 0.892, followed by Microsoft Office suite having RII of 0.881. Computer-Aided Design is not much behind with RII of 0.811. Software applications next in line are free cloud computing, planning and scheduling software, video conferencing and quantity and cost estimation software. Web-based workflow management suites, building information modelling (BIM) and paid cloud computing remained least considered with RII less than 0.6. RII for BIM came as a shock, as it is not faring well in the Pakistan's CI, despite its immense utility.

4.5. Functions Performed by ICTs on Construction Sites

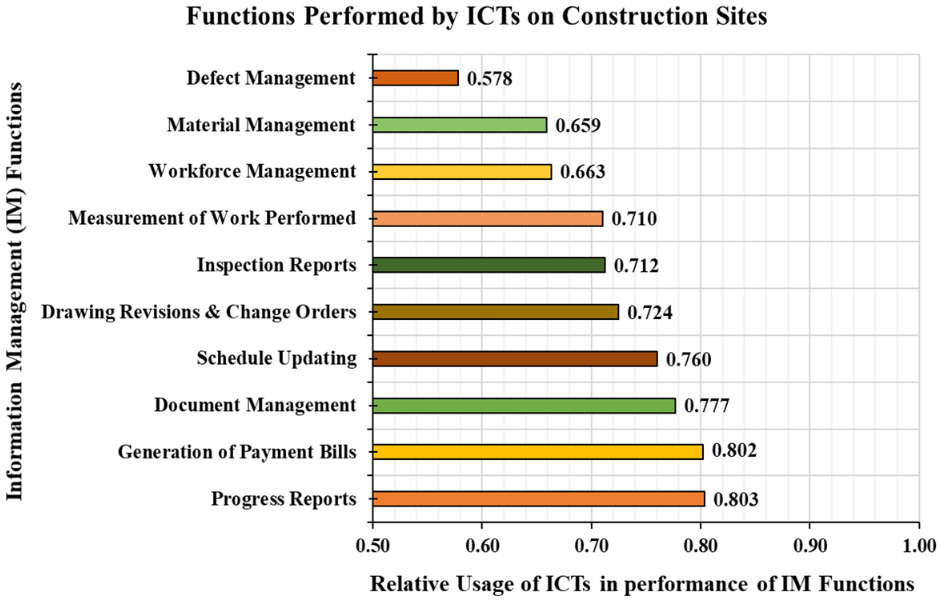

Figure 12:Functions Performed by ICTs on Construction Sites

The data on the construction management activities necessitating ICTs for IM was collected from the respondents. Fig. 12 explains that at Pakistan's construction sites, ICTs are most incorporated for generating progress reports and payment bills. After these two, ICTs are important for document management and schedule updating. ICTs use decreases towards actual construction execution processes namely workforce, material and defect management.

4.6. Satisfaction Level of Construction Professionals with Present Information Management Practices

Normally, Pakistan’s CI reflects the inappropriate and ineffective IM practices; however, a detailed survey depicted the true picture. Fig. 13 represents the overall satisfaction of CI professionals with their IM practices. 11 (6.11%) respondents were very unsatisfied, 51 (28.33%) were unsatisfied and 65 (36.11%) were neutral about their management of project information. This means that a collective of 70.56% were not satisfied with their IM practices. Further, satisfaction across different organization types and organization roles is explained in Fig. 14 and Fig. 15, respectively.

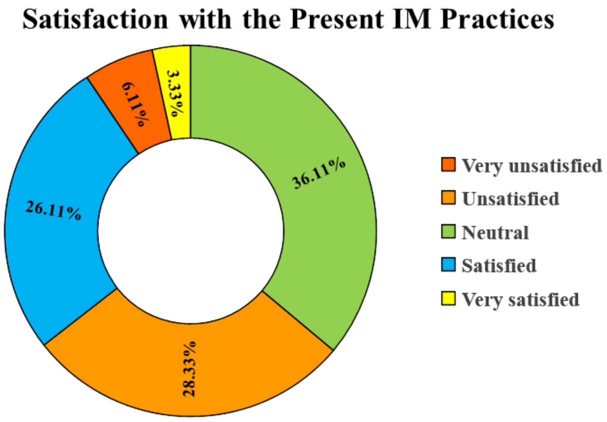

Figure 13: Satisfaction with the Present IM Practices

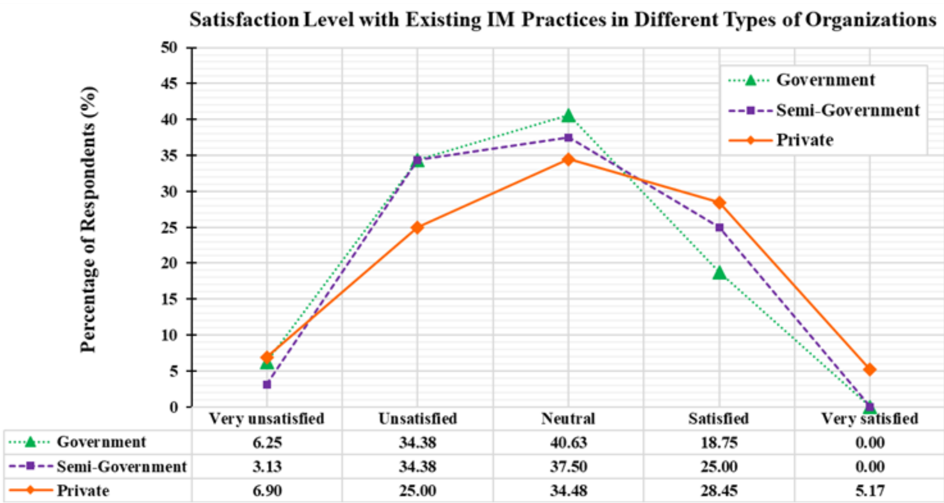

Figure 14: Satisfaction with the Existing IM Practices in Different Types of Organizations

Fig. 14 shows satisfaction trends across different types of organizations. Private organizations had lesser unsatisfied personnel than the government and semi-government organizations. The latter two have left skewed distribution curve, which shows that most of their technical personnel were not content with their IM practices. Government related personnel were least satisfied, followed by those of semi-government. 5% of private organizations were very satisfied, but none of such could be found in government and semi-government organizations.

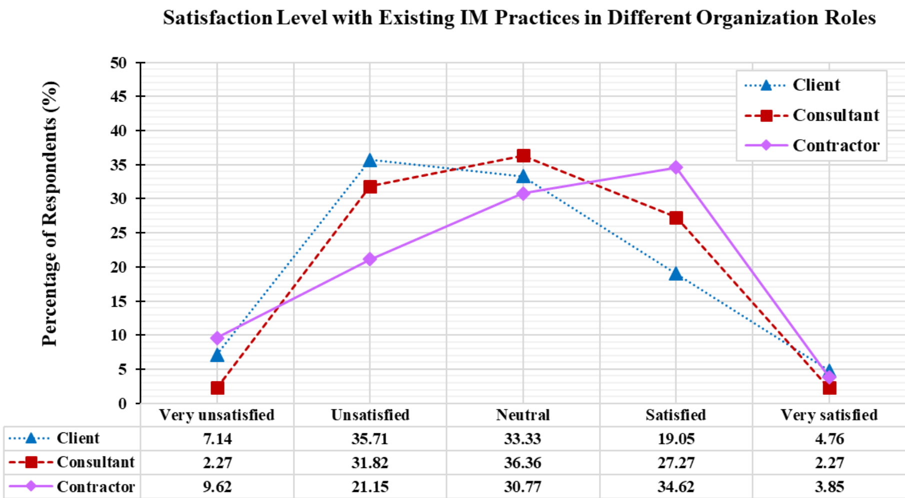

Figure 15: Satisfaction with the Existing IM Practices in Different Organization Roles

Fig. 15 describes the satisfaction of respondents with their IM practices in different organization roles. Consultant organizations personnel were nearly equally distributed in their level of satisfaction, unlike the client side which were more unsatisfied than satisfied, and contractor side which were other way round. CI professionals working with contractor organizations seemed to be focusing more on the work progress than on allied, but essential, IM which actually disrupts progress.

4.7. Barriers to Adoption of Modern Information and Communication Technologies

Respondents were asked to specify the impact of ten enlisted barriers, which hinder the adoption of modern information and communication technologies (ICTs) for information management (IM) on construction sites. The results are presented in Figure 16. According to the respondents, these are three most significant barriers: lack of awareness about the gains made by adoption of ICTs, lack of standard working practices among the stakeholders, as well as the lack of concern shown by the top hierarchy. Furthermore, lack of knowledge about ICTs is ranked as fourth most strong barrier in adoption of ICTs. Temporary nature of construction projects and multiple parties working on single project, which are also the characteristics of construction industry are considered least significant barriers by the respondents.

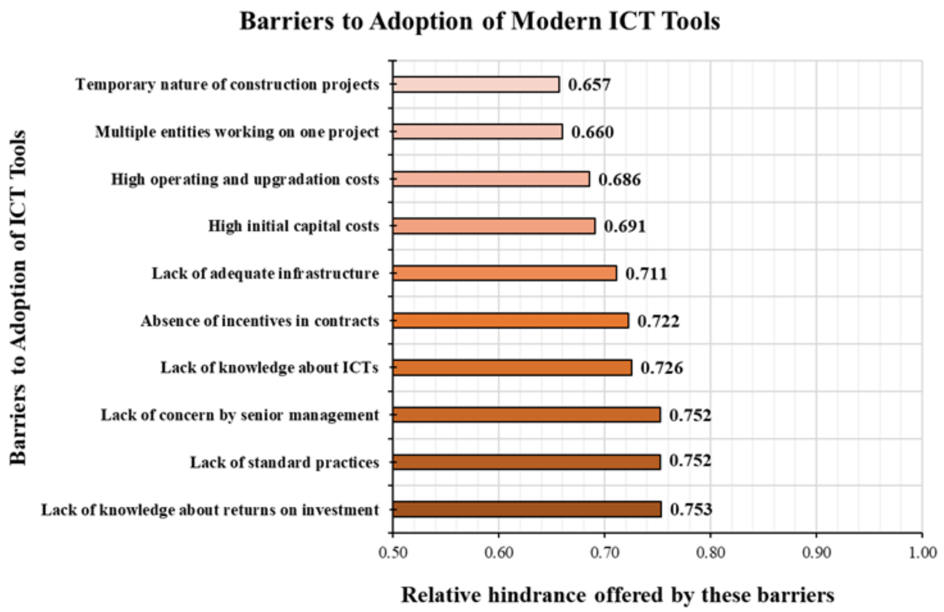

Figure 16: Barriers to Adoption of Modern ICT Tools

4.8. Requirements for Effective Information Management Practices

For adoption of ICTs, it is necessary that they facilitate the IM practices. In this section, respondents highlighted the importance of enlisted factors which are yardstick of IM practices. Fig 17 plots the results of responses. Most respondents opined, and it is self-explanatory, that best IM practice was that which leads to efficient communication with project participants. Secondly, which improves efficient on-site data capture, and thirdly, is simple and user-friendly. Thereafter, IM practices need to be economical and profitable for the organization, promoting standard working practices and to have least paperwork involved. In addition, effective IM practices require to promote intra- and inter-organizational integration and be adaptable to project environment.

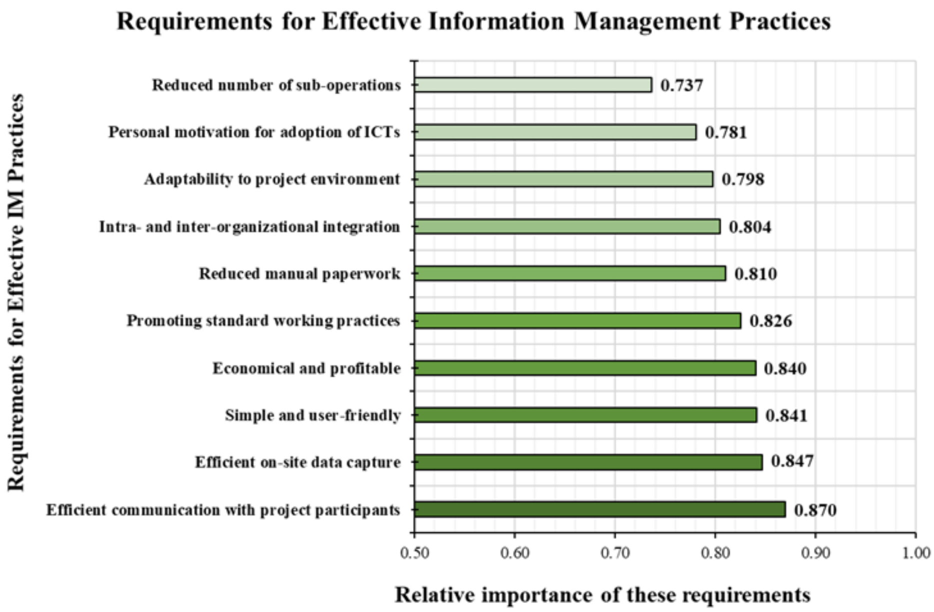

Figure 17: Requirements for Effective Information Management Practices

4.9. Ranking of Information and Communication Technologies for Construction Sites

After the assessment of barriers to adoption of information and communication technologies (ICTs) and of requirements to be met for effective information management (IM) practices, the respondents were asked to rank the three currently most useful hardware and software ICTs for construction sites. The responses to this part of the questionnaire are presented in Table 4.9.1 and Table 4.9.2.

4.2.1 Hardware

In the case of hardware, respondents chose desktop computers / laptops, smart phones / tablets, and intranet and internet modems as the top three ICTs for construction sites. Analyzing the data aforementioned in the *Section 4.4.1 Awareness and Proficiency in ICTs – Hardware*, it can be noted that these three hardware are in this respective order, the most well-known hardware on the construction site, and thus the first choice.

Further to state, biometric attendance machines are the next choice which have high utility in the workforce management and their salaries. Drone cameras, personal digital assistants and GPS receivers are next in line of the utility ranking. RFID Detectors, laser scanners and barcode readers remained unappreciated.

Table 0-1: Hardware ranked by the CI Professionals

Rank	ICT - Hardware	Votes	Percentage
1	Desktop computers / laptops	151	83.89%
2	Smart phones / tablets	143	79.44%
3	Intranet and Internet Modems	62	33.89%
4	Biometric Attendance Machines	51	28.33%
5	Drone Cameras	50	27.78%
6	Personal digital assistants	32	17.78%
7	GPS Receivers	28	15.56%
8	RFID Detectors	9	5.56%
9	Laser Scanners	8	4.44%
10	Barcode Readers	6	3.33%

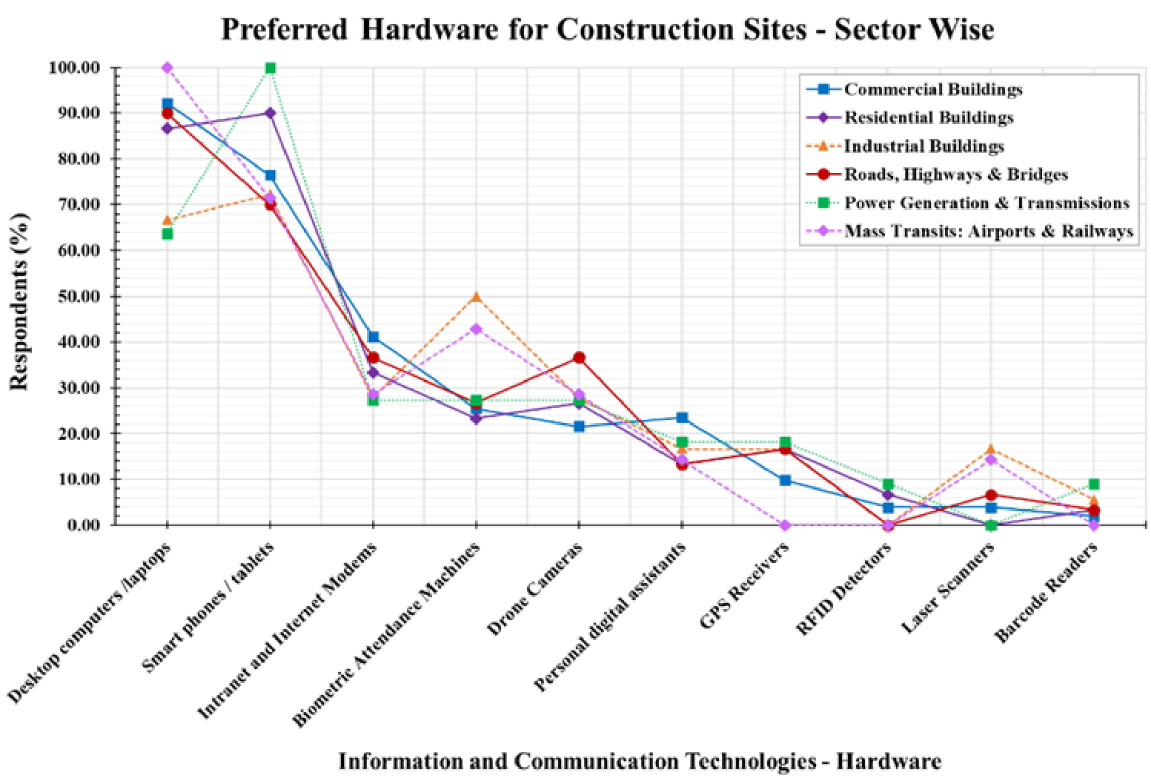

Figure 18: Preferred Hardware for Construction Sites – Sector Wise

When data in Table 2 is broken down, it can be seen that which ICT was preferred in different sectors of CI: the results are shown in Fig. 18. Some eccentricities can be noticed, like in roads, highways and bridges, and power generation and transmission, the smart phones/tablets were more preferred than the desktops/laptops unlike in other sectors. Likewise, biometric attendance machines were preferred most in mass transits and industrial building projects.

4.2.2 Software

The results of respondents' software preference are given in Table 3. Microsoft Office, planning and scheduling software, and email services occupied the top three positions, respectively. Thereafter, respondents showed interest in computer-aided design and building information modelling (BIM). Contrary to the rank of BIM in level of awareness, Section 4.2.1, it rose from ninth position to fifth. Quantity and cost estimation software and free cloud computing were seen next in preference list. Video conferencing and paid cloud computing could not yet capture the attention of CI professionals, despite their immense utility.

Table 0-2: Software ranked by the CI Professionals

Rank	ICT - Software	Votes	Percentage
1	Microsoft Office	145	80.56%
2	Planning & Scheduling Software	95	52.78%
3	E-mail Services	84	46.67%
4	Computer-Aided Design	74	41.11%
5	Building Information Modelling - BIM	47	26.11%
6	Quantity & Cost Estimation Software	38	21.11%
7	Free Cloud Computing	21	11.67%
8	Web-based Workflow Management	16	8.89%
9	Video Conferencing	13	7.22%
10	Paid Cloud Computing	7	3.89%

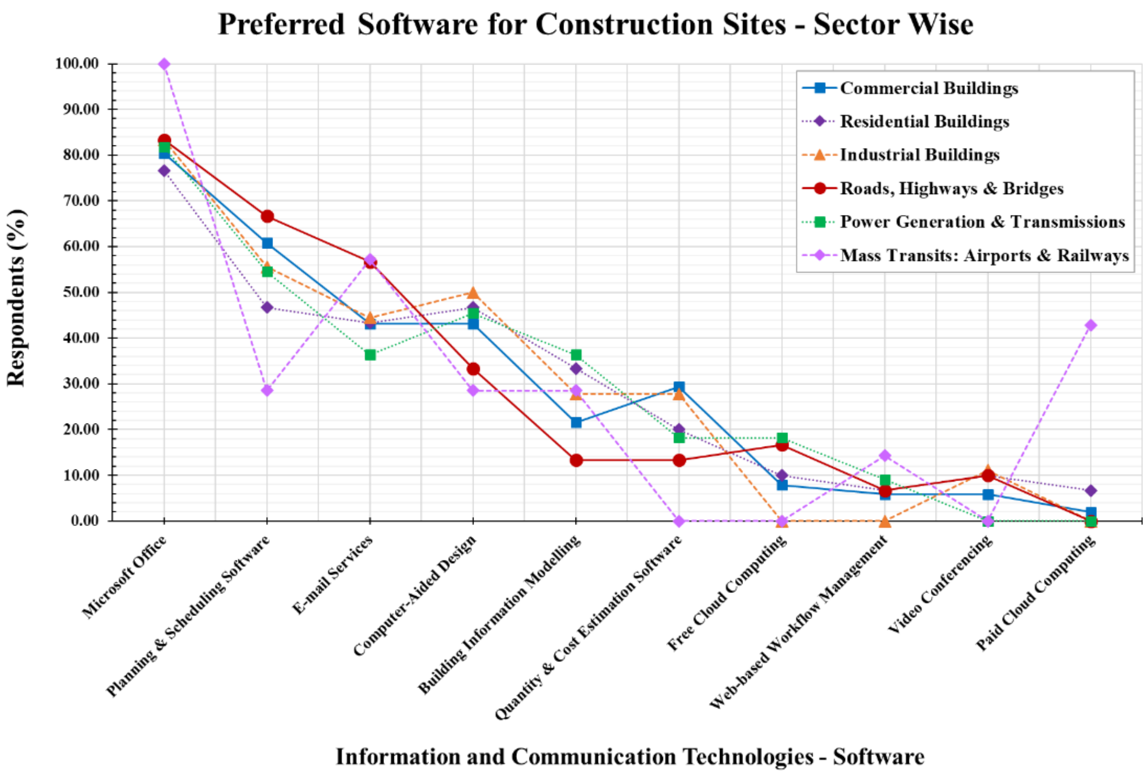

Figure 19: Preferred Software for Construction Sites – Sector Wise

Fig. 19 is the breakdown of the preference of ICTs-Software. Each CI sector considered Microsoft Office as the necessity, followed by planning and scheduling software. Mass Transit sector was an anomaly, as it weighed email services more than the planning and scheduling software, and its respondents also had higher consideration of paid cloud computing, after the Microsoft office and email services. Other sectors followed nearly a same trend for different software applications suited for CI.

4.10. Information and Communication Technologies based Information Management Framework

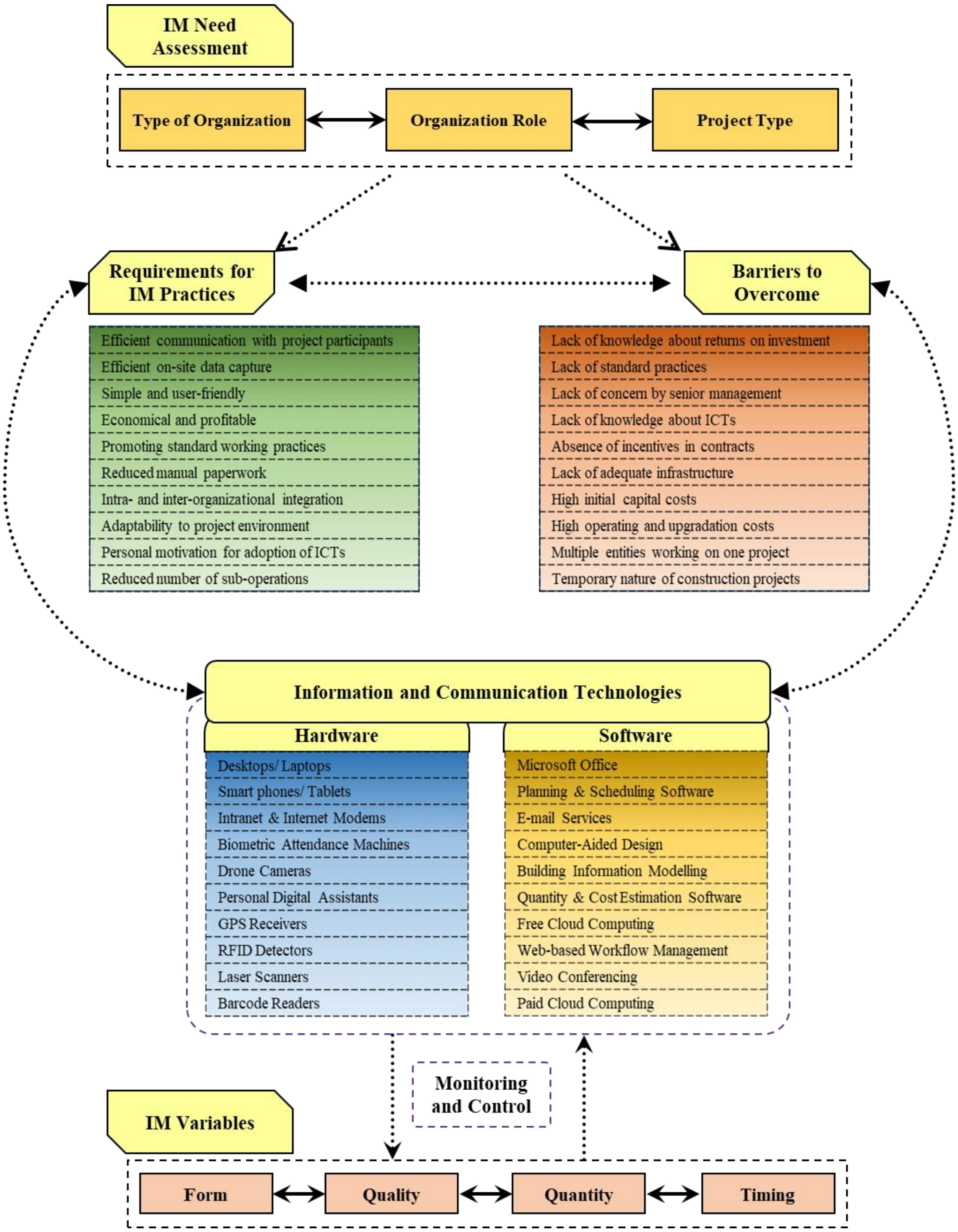

Figure 20:Proposed Information Management Framework for Construction Industry

The information management (IM) framework presented in Fig. 20 is proposed for the construction industry (CI) for performance enhancement through standardization of IM practices and using information and communication technologies (ICTs). It begins with the IM need assessment, which pertains to the different information flows and among different number and nature of stakeholders depending upon the organization type and role as well as the project type. Project managers may undertake a detailed review of their specific IM needs. After a comprehensive IM need assessment, follows the two simultaneous processes for adoption of ICTs. First is the selection of ICT based on satisfaction of IM needs for that particular project. And, second is the overcoming the barriers to adoption of ICTs. The top ten requirements and barriers, research from literature and ranked by the respondents of Pakistan's CI, are given as well for the reference. Thereon, the ICTs meeting the requirements of the specific construction project may be selected from the lists provided and categorized in to hardware and software. Final step refers to the monitoring and control of IM. ICTs adopted for the project may be regulated and reviewed for their satisfaction of the IM's four variables: form, quality, quantity and timing of the information. When the adopted ICT(s) fulfil the project's IM requirements and satisfy the stakeholders in aforementioned IM variables, the framework may itself be considered as success-enabler for the CI.

4.11. Validation of the Information Management Framework

Abowitz and Toole (2010) and Lucko and Rojas (2010) have given different approaches to validation for research in CI, including focused groups, case study approaches and criteria-based approaches. For this research, the technique followed is of Aziz (2016) which uses four criteria to evaluate performance indicators for management process assessment; these are: appropriateness, comprehensiveness, accuracy and relevance. 12 CI managers were asked to evaluate the proposed IM framework by envisioning the incorporation of framework in the planning stage of construction projects and considering the criteria aforementioned. The response was positive and it was acknowledged that its relevance and usability is considerable: it undertakes the IM planning, ICTs as means, overcomes barriers, and monitors the IM processes and ICTs on KPIs.

Chapter - 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Information management (IM) lays the foundation of effective communication and collaboration among the various stakeholders in the construction projects. Information and communication technologies (ICTs) are the vehicles of IM. Pakistan's construction industry (CI) is lagging behind in the adoption of ICTs and therefore lacks proper IM on construction sites. The study uses questionnaire to determine the current IM practices in Pakistan's CI: awareness of CI professionals about their current usage of ICTs in IM and their overall satisfaction with the IM practices. Industry professionals are only familiar with a few ICTs, lack working experience in major globally employed ICTs and about 71% remain below satisfaction line.

The study also produced the weighted list of barriers to ICT adoption and the key requirements for an ICT to be adopted for construction projects. Lack of knowledge about investment returns, lack of standard practices, and lack of concern by senior management are the main hindrances in the adoption of ICT in CI. While, CI professionals consider ICTs for adoption which yield efficient communication with project participants, efficient on-site data capture, and simple and user-friendly interfaces.

Thereafter, based on the survey data and literature, an IM framework is proposed that leads to better decision-making in IM planning and ICT selection and adoption. The framework determines the IM needs before proceeding to ICT selection and adoption phase. It overcomes the barriers to ICTs adoption and selects ICTs which satisfies project requirements; monitoring of IM variables (form, quality, quantity and timing) proceeds in parallel to project execution. The framework has been validated through a criteria-based approach, which included: appropriateness, comprehensiveness, accuracy and relevance. CI professionals agreed upon the suitability of IM framework and to increase the adoption of ICTs for performance enhancement of the CI. The outcomes of the research include, but are not limited to, the understanding about current IM practices and role of ICTs in these, significance level of various barriers to ICT adoption and requirements in ICTs in improving IM, a framework facilitating IM plan, processes and usage of ICTs. In sum, this study has paved the way for CI to keep abreast with the other industries in adopting modern tools for IM which in turn will lead to, besides improving project's internal and external communication, enhancement of project performance.

5.2 Recommendations

This study has paved the way for CI to keep abreast with the other industries in adopting modern ICTs for IM which in turn will lead to, besides improving project's internal and external communication, enhancement of project performance.

Future studies can focus on the investment decisions for adoption of ICTs, evaluate case studies and undertake pilot projects with regard to improving information management.

References

1. Abowitz, D. A. & Toole , T. M., 2010. Mixed method research: Fundamental issues of design, validity, and reliability in construction. *Journal of Construction Engineering and Management,* 136(1), pp. 108-116.

2. Abudayyeh, O. & Al-Battaineh, H. T., 2003. As-Built Information Model for Bridge Maintenance. *Journal of Computing in Civil Engineering,* 17(2), pp. 105-112.

3. ACI 318, 2014. *Building Code Requirements for Structural Concrete (ACI 318-14),* s.l.: American Concrete Institute.

4. Adriaanse, A., Voordijk, H. & Dewulf, G., 2010. The use of interorganisational ICT in United States construction projects. *Automation in Construction,* 19(1), pp. 73-83.

5. Ahuja, V., Yang, J. & Shankar, R., 2009. Study of ICT adoption for building project management in the Indian construction industry. *Automation in Construction,* 18(2009), pp. 415-423.

6. Al-Maatouk, Q. & Othman, M. S., 2018. A Framework for Collaborative Information Management in Construction Industry.. *International Journal of Advanced Intelligence Paradigms,* 11(1-2).

7. Ameh, O. J. & Daniel, E. I., 2017. Human Resource Management in the Nigerian Construction Firms: Practices and Challenges. *Journal of Construction Business and Management,* 2(1), pp. 47-54.

8. Anderson, J. et al., 2000. A Framework for Measuring IT Innovation Benefits. *Journal of Information Technology in Construction,* Volume 5, pp. 57-72.

9. Azhar, N., Kang, Y. & Ahmad, I., 2014. Critical Look into the Relationship between Information and Communication Technology and Integrated Project Delivery in Public Sector Construction. *Journal of Management in Engineering,* pp. 04014091-1-12.

10. Aziz, F., Rankin, J. H. & Waugh, L. M., 2016. Construction organizational-level information management framework. *Journal of Management in Engineering,* 32(2), pp. 1-10.

11. Aziz, F., Rankin, J. H. & Waugh, L. M., 2016. Construction Organizational-Level Information Management Framework. *Journal of Management in Engineering, ASCE,* 32(2), p. 04015043.

12. Bjork, B.-C., 2003. Electronic Document Management in Construction - Research Issues and Results. *ITcon,* 8(2003), pp. 105-117.

13. Brandon, P., Li, H. & Shen, Q., 2005. Construction IT and the 'tipping point'. *Automation in Construction,* 14(2005), pp. 281-286.

14. Choo, C. W., 2002. *Information Management for the Intelligent Organization: The Art of Scanning the Environment.* 3rd Edition ed. Medford, NJ: asis, ASIS Monograph Series.

15. Ciftcioglu, Ö., 2003. Classification of Construction Information with Fuzzy Attributes. *Construction Informatics Digital Library*.

16. Dawood, N., Akinsola, A. & Hobbs, B., 2002. Development of automated communication of system for managing site information using internet technology. *Automation in Construction,* 11(2002), pp. 557-572.

17. Dehlin, S. & Olofsson, T., 2008. An Evaluation Model for ICT Investments in Construction Projects. *IT Con,* Volume 13, pp. 343-361.

18. Demian, P. & Walters, D., 2014. The advantages of information management through building information modelling. *Construction Management and Economics,* 32(12), pp. 1153-1165.

19. Detlor, B., 2010. Information management. *International Journal of Information Management,* 30(2010), pp. 103-108.

20. Farooqui, R. U. & Ahmed, S. M., 2008. Assessment of Pakistani Construction Industry - Current Performance and the Way Forward. *Journal for the Advancement of Performance Information and Value,* 1(1), pp. 51-72.

21. Feibel, J. B., 2003. *Investment Performance Measurement.* New York: Wiley Finance.

22. Gao , T. et al., 2012. Development of a Framework for Identifying Information Bottlenecks and Evaluating Different Data Capture Technologies to Support Proactive Productivity Management. *Construction Research Congress, ASCE,* pp. 356-365.

23. Giel, K. B. & Issa, R. R., 2013. Return on Investment Analysis of Using Building Information Modeling in Construction. *Journal of Computing in Civil Engineering,* Volume 27, pp. 511-521.

24. Golparvar-Fard, M., Peña-Mora, F., Arboleda, C. A. & Lee, S., 2009. Visualization of Construction Progress Monitoring with 4D Simulation Model Overlaid on Time-Lapsed Photographs. *Journal of Computing in Civil Engineering, ASCE,* Nov-Dec, 23(6), pp. 391-404.

25. Hegazy, T. & Abdel-Monem, M., 2012. Email-based system for documenting construction as-built details. *Automation in Construction,* 24(2012), pp. 130-137.

26. International Telecommunication Union, 2017. *Measuring the Information Society Report 2017.* [Online]
Available at: http://www.itu.int/net4/ITU-D/idi/2017/

27. Kelley, J., 2002. *Knowledge Nirvana.* 1st ed. Fairfax(VA): Xulon Press.

28. Khan, K. I. A., Flanagan, R. & Lu, S.-L., 2016. Managing information complexity using system dynamics on construction projects. *Construction Maangement and Economics,* 34(3), pp. 192-204.

29. Kumar, B. & Cheng, J. C. P., 2010. *Cloud computing and its implications for construction IT.* Nottingham, UK, The 13th International Conference on Computing in Civil and Building Engineering (ICCCBE XIII).

30. Lee, D.-Y.et al., 2016. A linked data system framework for sharing construction defect information using ontologies and BIM environments. *Automation in Construction,* 68(2016), pp. 102-113.

31. Lee, N. & Kim, Y., 2018. A Conceptual Framework for Effective Communication in Construction Management: Information Processing and Visual Communication. *Construction Research Congress, ASCE*, pp. 531-541.

32. Lee, S.-K. & Yu, J.-H., 2012. Success model of project management information system in construction. *Automation in Construction,* 25(2012), pp. 82-93.

33. Liew, A., 2007. Understanding Data, Information, Knowledge And Their Inter-Relationships. *Journal of Knowledge Management Practice,* 7(2).

34. Lucko, G. & Rojas, E. M., 2010. Research Validation: Challenges and Opportunities in the Construction Domain. *Journal of Construction Engineering and Management,* 136(1), pp. 127-135.

35. Lundkvist, R., Meiling, J. H. & Sandberg, M., 2014. A proactive plan-do-check-act approach to defect management based on a Swedish construction project. *Construction Management and Economics,* 32(11), pp. 1051-1065.

36. Lu, W., Huang, G. Q. & Li, H., 2011. Scenarios for applying RFID technology in construction project management. *Automation in Construction,* 20(2011), pp. 101-106.

37. Madhavarao, B., Mahindra, K. & Asadi, S., 2018. A critical analysis of material management techniques in construction project. *International Journal of Civil Engineering and Technology,* 9(4), pp. 826-835.

38. Marsh, L. & Flanagan, R., 2000. Measuring the costs and benefits of information technology in construction. *Engineering, Construction and Architectural Management* , 7(4), pp. 423-435.

39. Martinez-Rojas, M., Marin, N. & Vila, M. A., 2015. The role of information technologies to address data handling in construction project management. *Journal of Compting in Civil Engineering, ASCE,* 30(4), pp. 04015064-1-20.

40. Mbazor, D. N. & Adedayo, A. M., 2018. The imperativeness of information management on housing project delivery. *International Journal of Advanced Engineering and Management Research,* 3(2), pp. 76-86.

41. Mell, P. & Grance, T., 2011. *The NIST Definition of Cloud Computing,* s.l.: National Institute of Standards and Technology.

42. Miettinen, R. & Paavola, S., 2014. Beyond the BIM utopia: Approaches to the development and implementation of building information modeling. *Automation in Construction,* 43(2014), pp. 84-91.

43. Ministry of Finance, 2017. *Overview of the Economy, 2016-17,* s.l.: s.n.

44. Ozorhon, B., Karatas, C. G. & Demirkesen, S., 2014. A Web-Based Database System for Managing Construction Project Knowledge. *Procedia - Social and Behavioral Sciences,* 119(2014), pp. 377-386.

45. Ruddock, L., 2006. ICT in the Construction Sector: Computing the Economic Benefits. *International Journal of Strategic Property Management,* Volume 10, pp. 39-50.

46. Saunders , M., Lewis, P. & Thornhill, A., 2009. *Research Methods for Business Students.* Fifth ed. Essex, England: Pearson Education Limited.

47. Senaratne, S. & Ruwanpura, M., 2016. Communication in construction: a management perspective through case studies in Sri Lanka. *Architectural Engineerinf and Design Management,* 12(1), pp. 3-18.

48. Sepasgozar, S. M. E., Lim, S., Shirowzhan, S. & Kim, Y. M., 2014. *Implementation of As-Built Information Modelling Using Mobile and Terrestrial Lidar Systems.* Sydney, The 31st International Symposium on Automation and Robotics in Construction and Mining (ISARC 2014), pp. 876-883.

49. Shahi, A., Haas, C. T., West, J. S. & Akinci, B., 2014. Workflow-Based Construction Research Data Management and Dissemination. *Journal of Computing in Civil Engineering, ASCE,* 28(2), pp. 244-252.

50. Shelbourn, M. A., Bouchlaghem, D., Anumba, C. & Carrillo, P., 2007. A framework for effective collaborative working in construction. *Management, Procurement and Law,* Issue MP0, pp. 1-9.

51. Solis, F. A. M., Howe, J. & O'Brien, W. J., 2015. Integration of Information Technologies into Field Managers' Activities: A Cognitive Perspective. *Journal of Management in Engineering, ASCE,* 31(1), p. A4014001.

52. Symons, V. J., 1991. Impacts of information systems: four perspectives. *Information and Software Technology,* 33(3), pp. 181-190.

53. Tsai, M.-K., Yang, J.-B. & Lin, C.-Y., 2007. Integrating wireless and speech technologies for synchronous on-site data collection. *Automation in Construction,* 16(2007), pp. 378-391.

54. Viljamaa, E. & Peltomaa, I., 2014. Intensified construction process control using information integration. *Automation in Construction,* 39(2014), pp. 126-133.

55. Voordijk, H. & Adriaanse, A., 2016. Engaged scholarship in construction management research: the adoption of information and communications technology in construction projects. 34(7-8), pp. 536-551.

56. Wilkinson, A., Johnstone, S. & Townsend, K., 2012. Changing patterns of human resource management in construction. *Construction Management and Economics*, 30(7), pp. 507-512.

57. Zhang, J. et al., 2017. A multi-server information-sharing environment for cross-party collaboration on a private cloud. *Automation in Construction*, 81(2017), pp. 180-195.

Annexure – A

RESEARCH QUESTIONNAIRE

Information Management using Information and Communication Technologies for Performance Improvement on Construction Sites

Dear Respondent,

This data collection is part of a graduate research which strives to achieve the following:

1. Determine the status of existing information management (IM) practices and usage of modern information and communication technologies (ICTs) in construction industry

2. Obtain input for the requirements and key performance indicators (KPIs) of effective information management practices.

3. Develop an information management framework for facilitating coordination and collaboration among stakeholders.

Your feedback in this regard will only be used for study purposes and will be treated as confidential.

Thanking you in advance for your cooperation.

Regards,

Abdul Wahab Safdar
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National University of Sciences & Technology (NUST)
H-12, Islamabad, Pakistan
Contact: +92-331-5231697
Email: abdul.wahab.535@gmail.com

* Required

Respondent Profile

1. **Name:** *

____

2. **Highest academic qualification:** *

Mark only one oval.

- ◯ Diploma
- ◯ Bachelors
- ◯ Masters
- ◯ Doctorate

3. **Professional Experience (in years):** *

Mark only one oval.

- 0 - 5
- 6 - 10
- 11 - 15
- 16 - 20
- 21 and above

4. **Organization Type:** *

Mark only one oval.

- Government
- Semi-Government
- Private

5. **Organization Role:** *

Mark only one oval.

- Client
- Consultant
- Contractor
- Designer
- Material Supplier
- Academia

6. **Current Project Type:**

* *Mark only one oval.*

- Residential Buildings
- Commercial Buildings
- Industrial Buildings
- Roads, Highways and Bridges
- Mass Transits: Airports and Railways
- Power Generation and Transmission
- Waterways and Pipelines
- Telecommunication
- Pre-cast building materials
- Research and Development
- Other: ______________________

7. Current Designation: *

____

Existing Information Management Practices

8. **Select your awareness and proficiency in hardware for Information Management:** *

Mark only one oval per row.

	Not Aware	Basic Awareness	Intermediate Awareness	Practical Usage	Expert Usage
Desktop Computers / Laptops	⬭	⬭	⬭	⬭	⬭
Smart Phones / Tablets	⬭	⬭	⬭	⬭	⬭
Personal Digital Assistants	⬭	⬭	⬭	⬭	⬭
Barcode Readers	⬭	⬭	⬭	⬭	⬭
RFID Detectors	⬭	⬭	⬭	⬭	⬭
GPS Receivers	⬭	⬭	⬭	⬭	⬭
Laser Scanners	⬭	⬭	⬭	⬭	⬭
Drone Cameras	⬭	⬭	⬭	⬭	⬭
Biometric Attendance Machines	⬭	⬭	⬭	⬭	⬭
Intranet and Internet Modems	⬭	⬭	⬭	⬭	⬭

9. **Select your awareness and proficiency in software for Information Management:** *

Mark only one oval per row.

	Not Aware	Basic Awareness	Intermediate Awareness	Practical Usage	Expert Usage
Microsoft Office (Word, PowerPoint, Excel)	⬭	⬭	⬭	⬭	⬭
Computer-Aided Design (AutoCAD)	⬭	⬭	⬭	⬭	⬭
E-mail Services	⬭	⬭	⬭	⬭	⬭
Quantity & Cost Estimation Software	⬭	⬭	⬭	⬭	⬭
Planning & Scheduling Software	⬭	⬭	⬭	⬭	⬭
Web-based Workflow Management	⬭	⬭	⬭	⬭	⬭
Building Information Modelling - BIM	⬭	⬭	⬭	⬭	⬭
Free Cloud Computing (e.g. Dropbox, Google Drive, etc.)	⬭	⬭	⬭	⬭	⬭
Paid Cloud Computing (e.g. Aconex, Procore, etc.)	⬭	⬭	⬭	⬭	⬭
Video Conferencing	⬭	⬭	⬭	⬭	⬭

10. **How much of these functions at your current project are performed by ICTs?** *
Mark only one oval per row.

	Hardly	Occassionally	Sometimes	Frequently	Always
Drawing Revisions and Change Orders	⬭	⬭	⬭	⬭	⬭
Inspection Reports	⬭	⬭	⬭	⬭	⬭
Progress Reports	⬭	⬭	⬭	⬭	⬭
Schedule Updating	⬭	⬭	⬭	⬭	⬭
Material Management	⬭	⬭	⬭	⬭	⬭
Workforce Management	⬭	⬭	⬭	⬭	⬭
Document Management	⬭	⬭	⬭	⬭	⬭
Defect Management	⬭	⬭	⬭	⬭	⬭
Measurement of Work Performed	⬭	⬭	⬭	⬭	⬭
Generation of Payment Bills	⬭	⬭	⬭	⬭	⬭

11. **How satisfied are you with your information management practices?** *
Mark only one oval.

⬭ Very unsatisfied
⬭ Unsatisfied
⬭ Neutral
⬭ Satisfied
⬭ Very satisfied

<u>Barriers to Adoption of Modern Tools</u>

12. **Specify the effect of following barriers in adoption of ICTs:** *
Mark only one oval per row.

	Very Low	Low	Medium	High	Very High
Lack of knowledge about ICTs	⬭	⬭	⬭	⬭	⬭
Lack of standard practices	⬭	⬭	⬭	⬭	⬭
Lack of concern by senior management	⬭	⬭	⬭	⬭	⬭
High initial capital costs	⬭	⬭	⬭	⬭	⬭
High operating and upgradation costs	⬭	⬭	⬭	⬭	⬭
Lack of knowledge about returns on investment	⬭	⬭	⬭	⬭	⬭
Lack of adequate infrastructure	⬭	⬭	⬭	⬭	⬭
Absence of incentives in contracts	⬭	⬭	⬭	⬭	⬭
Multiple entities working on one project	⬭	⬭	⬭	⬭	⬭
Temporary nature of construction projects	⬭	⬭	⬭	⬭	⬭

Requirements for Effective Information Management Practices

13. **Specify the importance of following factors in information management:** *
Mark only one oval per row.

	Not important	Less important	Neutral	Important	Very important
Efficient on-site data capture	⬭	⬭	⬭	⬭	⬭
Reduced number of sub-operations	⬭	⬭	⬭	⬭	⬭
Reduced manual paperwork	⬭	⬭	⬭	⬭	⬭
Simple and user-friendly	⬭	⬭	⬭	⬭	⬭
Economical and profitable	⬭	⬭	⬭	⬭	⬭
Efficient communication with project participants	⬭	⬭	⬭	⬭	⬭
Promoting standard working practices	⬭	⬭	⬭	⬭	⬭
Intra- and inter-organizational integration	⬭	⬭	⬭	⬭	⬭
Personal motivation for adoption of ICTs	⬭	⬭	⬭	⬭	⬭
Adaptability to project environment	⬭	⬭	⬭	⬭	⬭

Ranking the Most Useful Hardware and Software for Construction Sites

14. Please select the top three Hardware suitable for information management on construction sites *
Select 3 only. *Check all that apply.*

- ☐ Desktop computers / Laptops
- ☐ Smart Phones / Tablets
- ☐ Personal Digital Assistants
- ☐ Barcode Readers
- ☐ RFID Detectors
- ☐ GPS Receivers
- ☐ Laser Scanners
- ☐ Drone Cameras
- ☐ Biometric Attendance Machines
- ☐ Intranet and Internet Modems
- ☐ Other: ____________________

15. Please select the top three Software suitable for information management on construction sites *

Select 3 only. *Check all that apply.*

- [ ] Microsoft Office (Word, PowerPoint, Excel)
- [ ] Computer-Aided Design (AutoCAD)
- [ ] E-mail Services
- [ ] Quantity & Cost Estimation Software
- [ ] Planning & Scheduling Software
- [ ] Web-based Workflow Management
- [ ] Building Information Modelling - BIM
- [ ] Free Cloud Computing (e.g. Dropbox, Google Drive, etc.)
- [ ] Paid Cloud Computing (e.g. Aconex, Procore, etc.)
- [ ] Video Conferencing
- [ ] Other: ____________________