THE IMPLEMENTATION OF ENTERPRISE RESOURCE PLANNING SYSTEMS IN ROADS AND INFRASTRUCTURE CONSTRUCTION COMPANIES IN DEVELOPING COUNTRIES

A Thesis

presented to

the Faculty of Engineering

at Notre Dame University-Louaize

In Partial Fulfillment

of the Requirements for the Degree

Master of Science in Civil Engineering – Transportation and Urban Planning

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by

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MAY 2022

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Acknowledgments

I would like to thank my esteemed supervisor, Dr. Dima Jawad, for her valuable supervision and support during this research. Additionally, I would like to express gratitude to Dr. Talal Salem for his constructive comments which were influential in finalizing my research.

Moreover, I would like to thank every member of BiBuilt Group that I consider my second family, and most importantly its general manager Mr. Bachir Yazbek who encouraged me to dig into the field of Construction Enterprise Resource planning systems and shared with me valuable advice from his experience.

I also appreciate the effort of all the participants and contributors in the in-depth interviews and survey that allowed me to reach the objectives of this study.

Finally, my gratefulness also goes out to my family and friends for their encouragement and support all through my studies.

Table of Contents

List of Figures

List of Tables

ABSTRACT

Construction Enterprise Resource Planning (CERP) systems are built to fit the needs of construction companies. The major modules that are required to be within this system include management of general contractors, subcontractors, financial work, accounting, payroll, logistics, workflow processes... The collected data are stored within one unique database. However, CERP systems are difficult to standardize and fit the need of all the companies.

Hence, this research focuses on the elaboration of a framework that displays the minimum required modules to be included within a CERP, specifically for road and infrastructure construction companies. This objective is achieved based on the literature review, several meetings elaborated with experienced people in the field, and the survey's results. A procurement module linked to the on-site deliveries is a first stone that should be developed and implemented. Then, budgeting and work progress modules must be added. Finally, timesheet and equipment follow-up modules need to be implemented. Besides, through this research, the benefits and the challenges faced due to the integration of CERP are also considered. These attributes are tackled through a survey distributed among different ERP users, technical observations, and meeting with experienced people in the field. Mainly, developing countries' lack of strict legislation, lack of good technological capabilities, and lack of educational competences are seen as major challenges. While the benefits gained have a major impact on the company's turnover in the long term. This is due to less time needed in achieving managerial tasks, reduction in costs, real-time follow-up, better data collection, and reporting especially through using interactive dashboards within the system. Combining all the data in a unique database

will make the elaboration of interactive dashboards and their integration easier. Therefore, the managers will follow up their resources through faster techniques and they will optimize the allocation of all their resources through good planning and clear projections. They will avoid delays since tracking the daily work will be simpler. Finally, an approximative cost is presented while taking into consideration the three phases suggested in the framework and the other necessary cost. Some limitations are encountered and must be considered in future work such as the cost, the company's size, development and implementation period, and type of work.

1. RESEARCH JUSTIFICATION AND OBJECTIVES

1.1. Introduction

In the mid-20th century, the industrial sector used the Material Requirements Planning (MRP) system to plan and help in the decision-making in the production process. It is a tool to optimize production while taking into consideration the current inventory, the production capacity, and the need of goods. After this stage, the Enterprise Resource Planning (ERP) systems are developed. These systems included different modules to help to manage and integrate the full business process. The advantage of an ERP system is its capacity to provide financing, manufacturing, supply chain, purchasing, selling, and planning in one single system (CFI Education Inc, 2021). These systems succeeded in the industry. Statistics show that the ERP software market around the world is more than $25 billion with a growth rate of 10% to 20% per year (Roul, 2021).

The completion of any construction engineering project passes by several stages. The larger the scale of the project is, the more complicated the tasks become, and the more critical management is required. Achieving any of these projects on time and within budget remains a huge challenge all over the world, specifically in developing countries. Some of the main obstacles that could arise might be due to unexpected weather conditions, bureaucracy, and most importantly: lack of proper planning, collaboration, execution, and follow-up. Hence, the integration of the ERP systems within the construction field is taking place to avoid failure of project completion in terms of quality, cost, and time. Several companies tried to implement Construction Enterprise Resource Planning (CERP) systems, however; different scenarios appeared. Some succeeded while others failed. And this belongs to several reasons.

Findings show that CERP systems are a must but at the same time their implementation is very crucial. One of the main reasons is due to the absence of standardized work in the construction field which makes the view ambiguous regarding which modules to adopt and how to proceed. Moreover, the pandemic worldwide increased the need to prioritize the implementation of a system that reduces the contact between the engineers and decreases the papers transmittals while encouraging real-time follow-up data from the offices.

1.2. Research objectives

An ERP system might include all the following modules: budgeting, cost control, procurement management, work progress management, revenues, inventory management, site operation, estimating and tendering, subcontractor management, asset management, document control, planning and scheduling, logistics, …

However, the implementation of these modules depends on several factors such as the size of the company, the number of employees, the need of the modules, the legislation in the country, the education and technical level of the users, and most importantly, the phases of implementation and deployment.

While being in the transition phase from an old system to a newer one, old habits will remain an obstacle for most of the users until they get used to and accept the change. Hence, implementing the system in different phases is very critical. And the choice of the correct module for each phase is also a dilemma. The efficiency of the work that is being achieved cannot decrease, the mistakes should be minimized, the construction will continue during this transition, and the loss of data is not accepted. Thus, following a

good strategy in the deployment of the correct modules at the correct time is always a matter to be investigated.

Hence, the first objective of this research is to suggest a framework elaborating on the minimum required modules for construction companies to adopt to reach a successful implementation of ERP systems.

Moreover, while buying any license from an existing platform, you might have the luxury to choose whatever modules they already have or a specific package they have specified. Its integration will be very fast since it is ready. Also, you might be able to do some adjustments to the system, however; the time required, and its success will not be guaranteed if the requested change belongs to modification in the code. It will require a lot of time and regression might appear. Additionally, the cost of such changes are very expensive. Therefore, starting from the beginning with a customized system especially in the construction field will take a longer time to be developed and deployed but less constraint in the modification. First, standardization of work between different companies is hard to be achieved which will reduce the success rate of a built-in system. Second, the end-users will face fewer constraints which will reduce the challenges that are expected to be encountered.

Thus, the benefits of a customized system are considered in this study.

The lack of confidence in the success of the ERP system and the importance of its usage are critical. Moreover, the cost of such systems is huge. Additionally, achieving the construction work in an unprofessional way especially in developing countries prevents the latter from adopting an ERP system that tracks each activity. Hence, studying the

challenges before implementing this system is important to avoid the failure of the system.

As a result, the challenges encountered in the implementation in developing countries are taken into consideration.

Finally, interactive dashboards are newly being integrated into construction companies and in management operations. In a single screen, data can be combined, and solid decision-making can be done. Moreover, they will display real-time data and performance indicators. However, the success of a good dashboard belongs to good data collection and integration in a database. Hence, the correlation between the ERP and the dashboards is very important and completes the job of the ERP system.

For that, investigating the importance of the integration of interactive dashboards the last objective tackled.

1.3. Research Novelty

To the author's best knowledge, none of the studies achieved tackled specifically the implementation of ERP systems for roads and infrastructure engineering construction companies in developing countries. Moreover, the encountered challenges and the importance of customization and integration of interactive dashboards are taken into consideration.

The following section presents a review of the previous work. It includes a brief history, the challenges, and barriers that construction companies are facing while adopting ERP systems, the benefits resulting from the usage of these systems, and the critical factors that lead to a successful implementation. Some researchers tried to quantify the success

of these systems and to suggest the required modules. Finally, the importance of customizing the system and its applications are presented.

2. LITERATURE REVIEW

2.1. History of ERP

Back in time, to organize their work, manufacturing industries based their production on the Material Requirement Planning (MRP) system. It was built to organize the storage and allocation of production materials. Then, this system was expanded to include the allocation of production equipment and labor, which represents the manufacturing process. This evolvement turned the system to be called Manufacturing Resource Planning or MRPII. The addition of several modules such as purchasing, financials, human resources, and other front-office applications improved the management of different operations across the industry and led to the creation of Enterprise Resource Planning (ERP) systems (Jingsheng Shi & Halpin, 2003). The growth of ERP systems was fast in the 1990s and passed the $10 billion in 1998 (Hill, 1999). In 2001, Chen recognized that the difference between MRPII and ERP belongs to the planning and scheduling of the resources belonging to the supplier resources and consumption (Chen, 2001). These systems provide a platform for different departments in an industry to share data and communicate through a fast process. Additionally, the information is stored under a common database (Vlachopoulou & Manthou, 2006). The main idea of ERP systems is to create a standard and synchronized base of information to improve the efficiency of the company (Chung, Skibniewski, Lucas Jr., & Kwak, 2008). Similarly, construction industries are searching for several solutions to improve their scheduling and planning and reduce their cost. Jingsheng Shi and Halpin, (2003) and Nitithamyong and

Skibniewski, (2004) agreed that in opposition to the standard system within typical industries, construction firms are so diverse and differ in strategies applied, length in time, required resources, … Also, the lack of the necessary technical staff and technical knowledge (Windapo, 2013). Moreover, remaining a strong competitor in the market demands continuity in technological innovations and sustainable solutions (Al Marri, 2014), along with the proper management of resources (Sutar, Kashid, & Deshmukh, 2016) and integration of operation flows using information technology (Estébanez, Trigo, & Belfo, 2016). Several ERP vendors can be stated such as SAP, Oracle, PeopleSoft, JD Edwards, Microsoft Dynamics, Infor ERP, etc. However, these packages were mainly designed for manufacturing industries, hence; they were not able to succeed within the construction field (Tatari, Castro-Lacouture, & Skibniewski, 2008). Furthermore, based on Shi and Halpin (2003), construction companies require specific functions: scheduling, planning, procurement, project-oriented, open, expandable, remotely accessible, etc. Thus, some ERP suppliers' companies developed construction ERP systems (Tatari, Castro-Lacouture, & Skibniewski, 2008).

2.2. Challenges and Barriers

Based on a study done by Zabjeck et al. (2009), only 10 % of the projects are regarded as successful projects. Hence identifying the major challenges and barriers are a must. These issues can be differentiated into three main categories: organizational, social, and technological. The regular change of requirements and flexibility in the organizational branch are disregarded in ERP systems (Khouadjia, Mezghiche, & Drissi, 2015). Hence, many challenges are encountered since the standardization of construction work is difficult. Shi and Halpin (2003) indicated that the absence of additional practical

functionalities such as functions to track earned value, % completion, project progress, scheduling, budgeting, procurement process, and reporting are considered a major barrier for ERP systems. These authors also emphasized the importance of fitting the ERP system to the size and scale of small to medium size construction companies. Also, the uniqueness of construction companies cannot be ignored. The major factors that are identified to be behind this high failure percentage are also related to users. Rejection, opposition, under-utilization, and poor technological capabilities are within this category (Luo & Strong, 2004). Additionally, users feel that the usage of these systems is not adequate and difficult (Kwak, Park, Chung, & Ghosh, 2011). The resistance to evolution and change from the staff, the reduced awareness, and the need for extensive training sessions have a major impact on showing constraints for the successful implementation of ERP systems in construction companies (Fleming, Lingard, & Wakefield, 2007). More specifically, for small to medium size construction organizations, the conservatism of the owner group, high rates of change in technology and business solutions, and lack of investments in training are elaborated as barriers. (Anderson, 2001). Moreover, Ahmed et al. (2003) highlighted that the complexity of ERP systems, high costs, and extensive training for the technical inspectors in the field can be a part of the obstacles faced especially since technical people may not have the required computer skills. Another category of constraints belongs to time and technology improvements. Taking a long time to implement ERP systems can offer competitors a luxury of time to improve and dominate the market (Webb, 1998). A study done by Negahban et al. (2011) confirmed the previously mentioned obstacles through the elaboration on a survey and then expanded on a decision-making model for small to medium size construction companies

to help them decide whether the application of ERP system within their organization is suitable or not. A more recent study, in 2018, confirmed the previous results and seconded on the uniqueness of construction companies and their extensive need for customization, the cost constraint, the high attachment to conserve the traditional way of work, and limited training. However, this study was done based on the Sri Lankan context and highlighted the lack of confidence present in this country to adopt ERP systems in the construction industry regardless of the benefits that ERP systems provide (Dilakshan, Disaratna, & Silva, 2018). Apart from this, the cost is a challenge for organizations. Chen (2001) noted that the total cost of ERP systems can compensate for up to 2 to 3% of the company's revenues. And this cost varies from $100K for small companies up to over $1 billion for large companies. Finally, the benefits of investments in ERP systems cannot be assessed in the short term. It needs about two to five years. And the common tool used to investigate its efficiency is the usage of cost-benefit analysis.

2.3. Benefits

The major benefits of ERP systems stated by Shi and Halpin are (1) information sharing, (2) transparency of management responsibilities, and (3) improved management efficiencies. (1) removes the possibility of entering the same data twice or more and helps in preserving a consistent way of data collection. Besides, it releases the barriers between different offices and improves communication between different departments. (2) is achieved by being able to assess who is responsible for each task, who validated the order, sent it to the correct department… In other terms, it helps to track responsibilities, whereas; following the traditional strategies a paper might be lost in a department while

the head of this department can claim that he has never received this paper. (3) provides real data on time. And thus, decisions that are forced to be delayed in the traditional type of work can now be taken. In his research, Ahmed et al. agreed with Shi and Halpin and mentioned that the implementation of ERP systems within construction companies strengthens the supply chain, enhances flexibility, improves decision making, and reduces project completion time and cost. Besides, based on Lee et al. (2004) several tasks are achieved in a faster duration such as issuing purchase orders, obtaining approvals and signatures, preparing invoices and submittals, preparing cheque requests and vouchers, and canceling an invoice. Additionally, reduction in working capital, improvement in the quality of work, increase in global competitiveness is also some of the remarkable benefits of ERP implementation that are elaborated by Dilakshan et al.

2.4. Critical Success Factors

To maximize the benefits of ERP systems, some critical factors need to be achieved and followed. These factors are best described as critical success factors. In 2003, a study was conducted having the main objective of understanding the success factors of ERP systems in large construction firms. On the one hand, it focused on the relation between information technology strategy and maturity and its role, and on the other hand, on the organizational change and implementation method. The results show that consistency within the previously mentioned aspects is necessary (Voordijk, Leuven, & Laan, 2003). Emphasizing the importance of success, management support, planning, training, and team involvement belong to the key success factors. Additionally, software selection, consultancy, and support are also required (Ferratt, Ahire, & De, 2006). Having the same purpose as Voordijk et al. (2003), but following a different strategy, AboAbdo et al.

(2019) investigated the critical factors affecting the success of ERP systems implementation in large construction firms as well. They elaborated on 26 factors and inserted them in a survey, distributed to ERP users, to come up with the most critical ones. The findings are compatible with the previous studies and incorporate the users' involvement, awareness, training and support, and implementation team composition. They agree with the previous findings on the effect of human factors on the success of ERP systems' implementation (AboAbdo, Aldhoiena, & Al-Amrib, 2019). Additional factors studied by Yang et al. (2007) enlarge the list of critical success factors. Besides the participants' role, they discussed the role of a coding system, priority of ERP functionality implementation, customization, consultant role, and subcontractor performances. They suggest checking the availability of these criteria and the required planning before starting the implementation of the system. However, they do recommend taking more case studies on their model. The traditional way of selecting the convenient ERP system consists of 4 stages. As a primary initiative, the IT department within the company specifies its requirements and sends a "request for proposals" (RFP) for several companies that develop ERP systems. By their turn, these companies will elaborate on RFP guidelines. Afterward, the construction firm will study each guideline and decide whether it fits its requirements or not to choose among them the most suitable one. Regardless of this strategy, a gap remains between the construction company's requirements and the developing team (Rybárová, Braunová, & Jantošová, 2016). Tatari and Skibniewski (2011) focused on the importance of firm readiness and firm commitment to reach a successful implementation. They have elaborated on a relationship between critical success factors and the construction enterprise information

system (CEIS). Thus, they have concluded that the increase in the appliance of the previously mentioned dimensions leads to an increase in the CEIS integration levels. Continuing with the same purpose, Ozorhon and Cinar (2015) studied the critical success factors of ERP implementation in the construction industry in developing countries. Their results were compiled with the previous findings.

2.5. Quantifying Success

However, some researchers tried to quantify the success of the implementation of ERP systems by developing some indicators, relationships, and models. Chung et al. (2008) provided some indicators to evaluate the success factors and then developed a model to analyze the relationship between the critical factors and success indicators. The model helps decision-makers to implement the most suitable ERP system. While the intention to use or the usage of the ERP system along with the progress and quality of ERP implementation are considered as the main success indicators. Another study elaborated on validating the improvement in managerial skills while using ERP systems to confirm that these systems lead to better decision-making in construction firms in Slovakia (Mesároš, Mandičák, Romanová, & Behúnová, 2017).

2.6. Modules

Hewavitharana and Perera (2019) established a logical framework that combines the organizational processes and ERP processes for construction companies, after studying the gap between construction and ERP procedures. The data were collected using a questionnaire survey that is developed using the listed criterion in PMBOK. The targeted people are CEOs, general managers, project managers, technical managers, IT officers, quantity surveyors, data entry operators, and stock keepers within contractors,

subcontractors, and clients in the mid-sized Siri-Lankan construction firms. The results were analyzed using the Chi-square technique. The largest gap belongs to inventory management while the lowest belongs to sub-contractors management. The major reasons leading to the largest gap are the variety of item codes, the incorrect process of purchasing procedures, unplanned payment methods, and the absence of a re-order level. Tables 1 till 4 show the major gaps at each module and the recommended solution to reduce this gap. To conclude, one of the most important features to take into consideration is to customize the ERP system, however; higher cost and longer time might be required to reach the implementation stage of the system (Mirian & Osvaldo, 2012). Furthermore, higher success rates are seen when the implementation of ERP modules is deployed in sequences not as a full bulk at a time (Hallikainen, Kivijärvi, & Tuominen, 2009). Thus, Hadidi et al. (2016) suggested a decision model for ERP modules implementation in Saudi Arabia that helps in choosing the best sequence for ERP modules in construction firms. First, the required modules are elaborated. Second, six benefit evaluation criteria are taken into consideration: cost, efficiency, decision making, information quality, user satisfaction, and organizational flexibility. These criteria are elaborated based on the literature review. Third, each module is evaluated versus the benefits criteria. Finally, the final ranking of each module is calculated. The modules are compatible with the ones listed by Hewavitharana and Perera (2019), and they are approved by the experts through the semi-structured interviews done. The results show that the highest index belongs to decision-making criteria and then improved efficiency, better information quality, cost reduction, improved flexibility, and user satisfaction, respectively. The top three modules to be implemented at the first stage are

ordered as follows: inventory control and logistics, procurement, project finance, and accounting.

2.7. Customization

ERP systems customization is defined by the changes done on ERP software to meet the client's needs. This customization could be divided into three categories: module customization, database customization, and source code customization. The easiest category belongs to module modifications and corresponds to the least risky part (Rothenberger & Srite, 2009). While the most complex one is the source of code customization. It reflects the changes made in the design of the software and other specific requirements (Scott & Kaindl, 2000). Parthasarathy and Sharna (2016) studied the impact of each category on the functionality, reliability, usability, and maintainability of the ERP software. The results show that customizing the modules does not affect any of the listed variables. While customizing the database impacts the functionality positively, it negatively affects usability and maintainability. Lastly, the customization of the source code impacts positively maintainability and usability, however; it negatively affects functionality. Having the same purpose of customizing the ERP system and thus meeting the required functionalities, Mahmood Ali (2017) elaborated on developing an in-house ERP system within construction companies if a convenient developing team exists. The results show the key factor that leads to the success of an ERP system development and implementation is the proper understanding of the business processes and their functions.

2.8. Interactive Dashboards

Moreover, visualizing the current data, the percent project completion, the projections on your plans, … are critical and enhance decision making and follow-up procedures. A recent study done proposes a modern dashboard to improve project control and help planners and decision-makers to act. Previously, the dashboards were used to envision planning and performance progress, while this research used the Last Planner System metrics to follow up and get alerted about the values using two interfaces: the lookahead and the weekly work plan. Its final visuals are described in the following figures 1 and 2. The available metrics are tasks anticipated (TA), tasks made ready (TMR), percent plan complete (PPC), percent required complete and ongoing (PRCO), percent complete new (PNC), required level (RL), completed uncommitted (CU), percent improvement complete (PIC), and the capacity to load ratio (CLR). These dashboards are applied to two case studies and show very helpful results, however; additional research is required to test the reliability and effectiveness of such dashboards (Hamzeh, et al., 2020).

Table 1 Major gaps for each module and Recommendations

(Hewavitharana & Perera, 2019)

Criteria	Reasons for Gap	Recommendation
Inventory Management	The Existence of several item codes	Standardize a unique item code
	Deficiency in the generation of MR, PO, and GRN	On-time generation of MR, PO, and GRN
	The incorrect sequence of purchasing procedure	Practicing the correct circulation of procedures up to the payment
	Ad-hoc behaviors in the Payment method	Appropriate top management involvement
	The absence of Re-Order level	Continuous Stock Updating
Finance	Delays in the authorization of payment	Initiation of online payment method
	Immoral reconciliation of transactions	Instantaneous actions for re-correction
	Long-term practiced erroneous accounting system	Maintain transparent and systematic accounting practice

Table 2 Major gaps for each module and Recommendations Continued

(Hewavitharana & Perera, 2019)

Criteria	Reasons for Gap	Recommendation
Site Operation	Generation of Redundant reports	Identification of reports according to the requirement
	Malpractices in report generation	Restriction of passing random data to the system
	Lack of required data in the reports for decision making	Appropriate Top management involvement in the report generation
	The inadequacy of capturing necessary data	Proper planning when structuring the report
	Ad-hoc behaviors in scheduling	Proper scheduling about expected scenarios concerning the environmental situations like weather conditions
	Extreme Over usage or under usage of resources	Maintain proper resource usage record and correct planning resource usage
Estimating and tendering	Inability to compare Planned, budgeted, and actual costing	Adherence to generate cost accordance with BOQ items
	Malpractices in rate analysis	Standardize the rates used within the construction projects
	The inability to achieve the profit goal	Activation of the realistic approach for estimation and tendering
	Excess of Variations	Hiring proper cost estimators to limit the variation
Subcontractor management	Biased ways of selecting subcontractors	Carry out background analysis of subcontractors in the selection process
	Lack of tracking the work done	Manipulating working progress according to the BOQ items
	Mixing up of subcontractor type	Analyzing the variation and initiating the required method to handle
	Ad-hoc practices in Subcontractor payment	Produce a systematic way of payment

Table 3 Major gaps for each module and Recommendations Continued

(Hewavitharana & Perera, 2019)

Criteria	Reasons for Gap	Recommendation
Petty cash	No proper estimation of petty cash usage	Allocating fixed and adequate petty cash after a proper feasible study
	Inappropriate usage of petty cash	Carrying out proper estimation of resource usage
	Ad-hoc reimbursement practices and poor control over petty cash	Carrying out a proper estimation of resource usage
	Immoral reconciliation of transactions	Carrying out transparent account practices
	Issues in authorization	Initiation of online authorization system
Asset Management	Malpractices in purchasing an asset	Call for quotations
	No periodical maintenance of machinery and plants	Maintain standard records
	No record of valuation methods	Maintaining a systematic way of evaluating assets
	No proper monitoring of the utilization of assets	Implementing a proper schedule on asset usage
	The absence of systematic ways to transfer assets	Implementing a proper schedule on asset usage

Table 4 Major gaps for each module and Recommendations Continued

(Hewavitharana & Perera, 2019)

Criteria	Reasons for Gap	Recommendation
HRM	Poor Communication between Top management and the Employees	Introducing flat hierarchy level
	Inefficiency in carrying out activities	Implementing a proper schedule on HR allocation
	Ad-hoc leave allocations	Initiation of a systematic approach to leave allocation
	Lack of technical training for employees	Arranging periodical training sessions
	No proper measurement of employee performance	Introducing a rewarding system
Purchases	Delays in approval and authorization processes	Initiation of the online system
	Biased method of selecting suppliers	Carry out a background analysis of the supplier in the selection process
	Malpractices in purchasing resources	Call for Quotations
	Displacement of MR, PO	Proper documentation
Project management	Inability to carry out cost variance analysis	Adherence to generate cost under BOQ items
	Manipulation of calculations	Providing the required level of authorization to access the information
	Malpractices in rate analysis	Standardize the rates used within the construction projects
	Inappropriate Practices in report generation	Restricting the pass in random data to the system
	Lack of scheduling, monitoring, and controlling activities	Usage of proper management tools
	Scattered data among projects	Implementing integrating tools

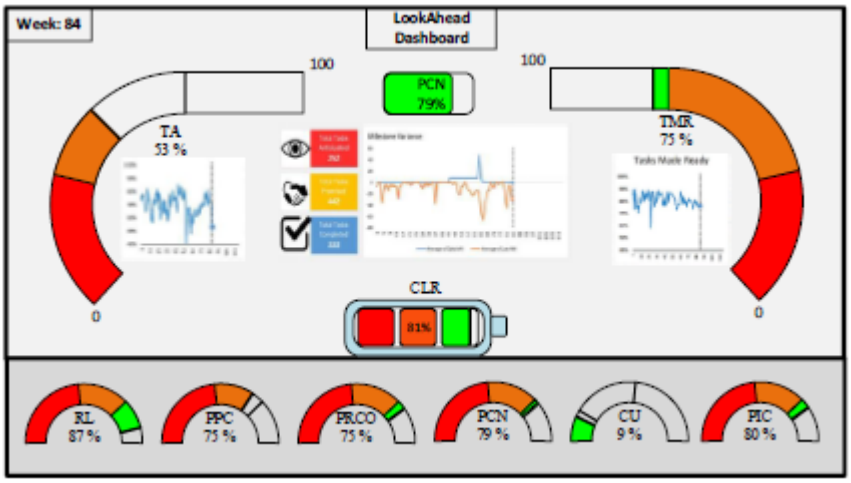

Figure 2 Proposed WWP Phase Dashboard Layout

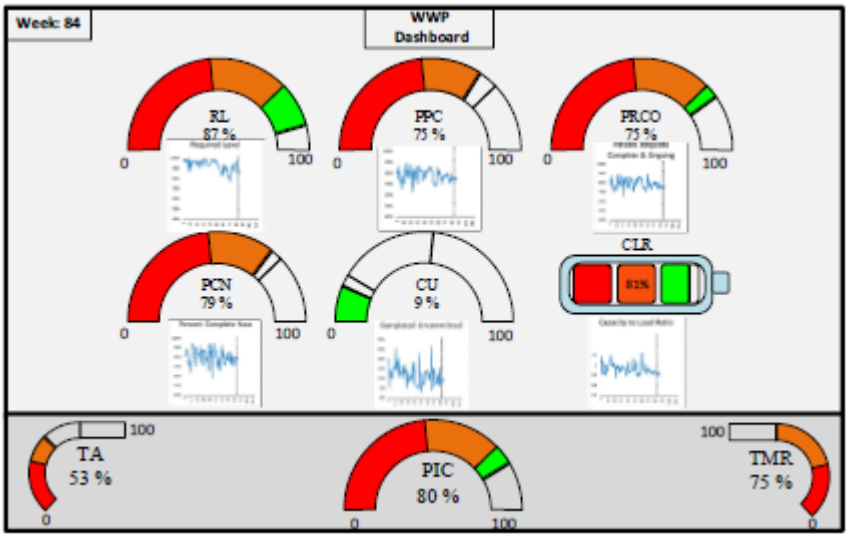

Figure 1 Proposed Lookahead Phase Dashboard Layout

3. RESEARCH PROCEDURE AND METHODS

Suggest a framework elaborating on the minimum required modules for construction companies to adopt to reach a successful implementation.

The data collected depended on interviews conducted with experienced people from the construction field. They are working on CERP systems or participated in developing the system. Moreover, technical observation is achieved by being part of a developing team and implementation team. The results are stated and compared to the literature review. Then, the proposed framework is established.

- Several Interviews with experienced people in the industrial and construction field.
- Several Interviews with experienced people in the development of customized ERP applications.
- Meetings with different clients in the construction fields requesting their needs.
- From one side, technical observation will be assessed by a group of civil engineers that are on site going forward in the implementation of the ERP system, and from the other side, it will be assessed by a group of engineers working on the development of the ERP. This team has started one year ago and gone over the discovery of an old ERP used, planning and design of a new ERP, development, testing, deployment, and ongoing support.

Investigate the benefits of a customized system, the challenges encountered in the implementation in developing countries.

A survey is conducted on a random sample of engineers, managers, and technical support members that are using an ERP system in construction companies located at Ivory Coast, Nigeria, Congo, and Lebanon. The first question of the survey requires the participant to specify when they started using an ERP system for the first time while the remaining questions are Likert scale questions and close-ended questions. The survey is attached in Appendix A.

- The survey is created on Google Form.
- The survey is shared by email.
- The results are collected and analyzed.

The importance of the integration of interactive dashboards.

A group of 17 questions is asked to project managers and general managers working in road and infrastructure construction companies to elaborate on the importance of interactive dashboards. The questions are asked during the ongoing support by the team, and they are attached in Appendix B.

- The questions are prepared on a google sheet and shared among the observer team.
- The answers are collected on this shared sheet.
- The results are analyzed.

Finally, the results of the previous sections are combined and discussed to optimize the suggested framework to be adopted to succeed in the implementation of ERP systems in road and construction companies in developing countries.

4. RESULTS AND ANALYSIS

4.1. RESULTS

The results are presented in the tables 5 till 17 and figure 3 below.

Survey: Part 1

Question: Have you ever used an ERP system? (Even if it includes only one module)

Table 5 Respondents results

50 Respondents	29 Yes	21 No

Question: Is the ERP used customized or not?

Table 6 Is the ERP used customized or not?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	I don't know	6	20.7	20.7	20.7
	NO	1	3.4	3.4	24.1
	YES	22	75.9	75.9	100.0
	Total	29	100.0	100.0	

Question: In which departments did you work?

- Transportation and Infrastructure Engineering/Contracting
- Cost control and Planning
- Accounting
- Project Control
- Operations

- IT
- Estimation Department
- Procurement Department

Question: Years of Experience

Varies between 2 and 17 years

Question: Education

Most of the responses correspond to civil engineers.

Question: Age

Average: 29 years

Question: Currently working

97% currently working

3% currently not working

Question: Regions/Countries

Lebanon, Saudi Arabia, Egypt, Sultanate Oman, UAE, Jordan, Nigeria, Congo, Ivory Coast, Europe, Africa

Survey: Part 2 - Suggested modules in a CERP system

Question: Have you ever used the following module? When (Year) if applicable?

Percent of users that utilized the following modules:

Table 7 Usage of each module

Module	Budgeting	Procurement	Work Progress	Inventory Management	Site operations
%	82.76	75.86	96.55	82.76	82.76
Earliest Year	2008	2005	2008	2010	2008
Latest Year	2021	2021	2021	2021	2021

Table 8 Usage of each module Continued

Module	Document Control	Planning and scheduling	Accounting	Tendering
%	75.86	58.62	68.97	51.72
Earliest Year	2007	2006	2010	2010
Latest Year	2021	2021	2021	2021

Survey: Part 3 - Benefits and Challenges

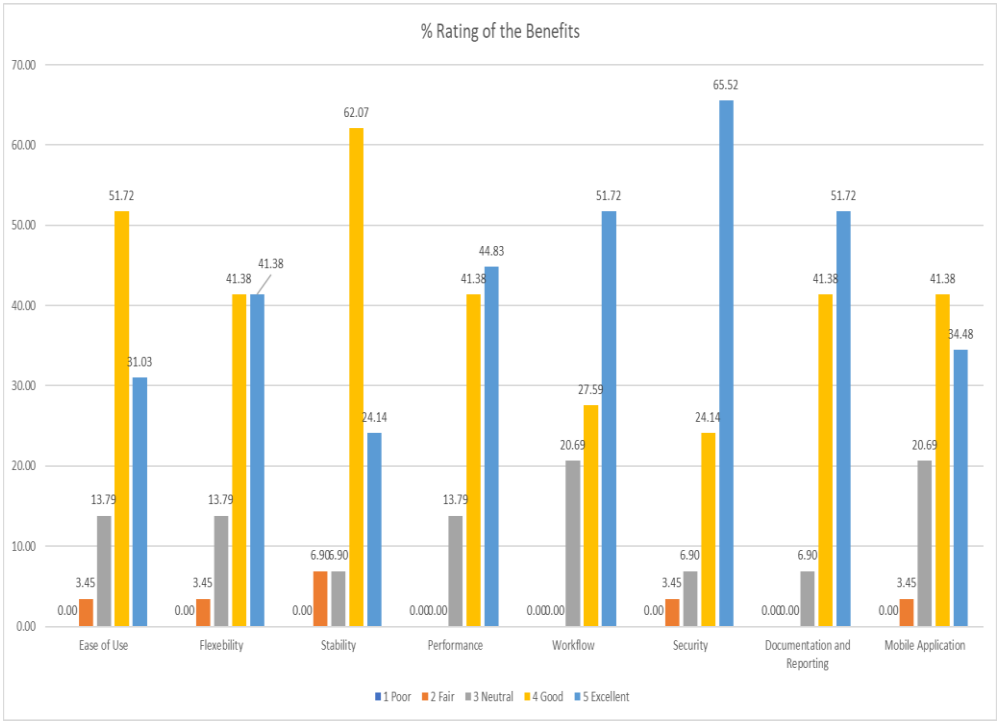

Figure 3 Rating of the Benefits

Table 9 Statistical Analysis of each Attribute

			Statistic	Std. Error
Ease of Use	Mean		4.10	.143
	95% Confidence Interval for Mean	Lower Bound	3.81	
		Upper Bound	4.40	
	5% Trimmed Mean		4.15	
	Median		4.00	
	Variance		.596	
	Std. Deviation		.772	
	Minimum		2	
	Maximum		5	
	Range		3	
	Interquartile Range		1	
	Skewness		-.684	.434
	Kurtosis		.552	.845
Flexibility	Mean		4.21	.152
	95% Confidence Interval for Mean	Lower Bound	3.90	
		Upper Bound	4.52	
	5% Trimmed Mean		4.27	
	Median		4.00	
	Variance		.670	
	Std. Deviation		.819	
	Minimum		2	
	Maximum		5	
	Range		3	
	Interquartile Range		1	
	Skewness		-.832	.434
	Kurtosis		.296	.845

Table 10 Statistical Analysis of each Attribute Ctd

			Statistic	Std. Error
Stability	Mean		4.03	.145
	95% Confidence Interval for Mean	Lower Bound	3.74	
		Upper Bound	4.33	
	5% Trimmed Mean		4.09	
	Median		4.00	
	Variance		.606	
	Std. Deviation		.778	
	Minimum		2	
	Maximum		5	
	Range		3	
	Interquartile Range		1	
	Skewness		-1.037	.434
	Kurtosis		1.790	.845
Performance	Mean		4.31	.132
	95% Confidence Interval for Mean	Lower Bound	4.04	
		Upper Bound	4.58	
	5% Trimmed Mean		4.34	
	Median		4.00	
	Variance		.507	
	Std. Deviation		.712	
	Minimum		3	
	Maximum		5	
	Range		2	
	Interquartile Range		1	
	Skewness		-.541	.434
	Kurtosis		-.798	.845

Table 11 Statistical Analysis of each Attribute Ctd

			Statistic	Std. Error
Workflow	Mean		4.31	.150
	95% Confidence Interval for Mean	Lower Bound	4.00	
		Upper Bound	4.62	
	5% Trimmed Mean		4.34	
	Median		5.00	
	Variance		.650	
	Std. Deviation		.806	
	Minimum		3	
	Maximum		5	
	Range		2	
	Interquartile Range		1	
	Skewness		-.645	.434
	Kurtosis		-1.136	.845
Security	Mean		4.52	.146
	95% Confidence Interval for Mean	Lower Bound	4.22	
		Upper Bound	4.82	
	5% Trimmed Mean		4.61	
	Median		5.00	
	Variance		.616	
	Std. Deviation		.785	
	Minimum		2	
	Maximum		5	
	Range		3	
	Interquartile Range		1	
	Skewness		-1.728	.434
	Kurtosis		2.753	.845

Table 12 Statistical Analysis of each Attribute Ctd

			Statistic	Std. Error
Documentatin and Reporting	Mean		4.48	.118
	95% Confidence Interval for Mean	Lower Bound	4.24	
		Upper Bound	4.72	
	5% Trimmed Mean		4.54	
	Median		5.00	
	Variance		.401	
	Std. Deviation		.634	
	Minimum		3	
	Maximum		5	
	Range		2	
	Interquartile Range		1	
	Skewness		-.836	.434
	Kurtosis		-.217	.845
Mobile Application	Mean		4.07	.156
	95% Confidence Interval for Mean	Lower Bound	3.75	
		Upper Bound	4.39	
	5% Trimmed Mean		4.11	
	Median		4.00	
	Variance		.709	
	Std. Deviation		.842	
	Minimum		2	
	Maximum		5	
	Range		3	
	Interquartile Range		2	
	Skewness		-.521	.434
	Kurtosis		-.389	.845

Table 13 Statistical Analysis of each Attribute Ctd

			Statistic	Std. Error
Less Work to Do	Mean		.72	.084
	95% Confidence Interval for Mean	Lower Bound	.55	
		Upper Bound	.90	
	5% Trimmed Mean		.75	
	Median		1.00	
	Variance		.207	
	Std. Deviation		.455	
	Minimum		0	
	Maximum		1	
	Range		1	
	Interquartile Range		1	
	Skewness		-1.059	.434
	Kurtosis		-.950	.845
Strict Measures to adopt ERP	Mean		.83	.071
	95% Confidence Interval for Mean	Lower Bound	.68	
		Upper Bound	.97	
	5% Trimmed Mean		.86	
	Median		1.00	
	Variance		.148	
	Std. Deviation		.384	
	Minimum		0	
	Maximum		1	
	Range		1	
	Interquartile Range		0	
	Skewness		-1.831	.434
	Kurtosis		1.446	.845

Table 14 Statistical Analysis of each Attribute Ctd

			Statistic	Std. Error
Relibale Upgrade	Mean		.90	.058
	95% Confidence Interval for Mean	Lower Bound	.78	
		Upper Bound	1.01	
	5% Trimmed Mean		.94	
	Median		1.00	
	Variance		.096	
	Std. Deviation		.310	
	Minimum		0	
	Maximum		1	
	Range		1	
	Interquartile Range		0	
	Skewness		-2.748	.434
	Kurtosis		5.961	.845
Continuous Support	Mean		.93	.048
	95% Confidence Interval for Mean	Lower Bound	.83	
		Upper Bound	1.03	
	5% Trimmed Mean		.98	
	Median		1.00	
	Variance		.067	
	Std. Deviation		.258	
	Minimum		0	
	Maximum		1	
	Range		1	
	Interquartile Range		0	

Targeted Questions

Table 15 Summary Results of Targeted Questions

As a project manager, engineer: how do you find the following attributes?	**Summary of the results**
Are you facing obstacles in convincing the users to adapt to the new customized system?	Yes, unless a strict decision was taken from the CEO, most of the users were opposed to cooperating and using the system.
Are you facing obstacles while teaching your staff to use the new customized ERP using new techniques: Tablets, Application through web…?	Some users learn very quickly, however; others might need more than 3 sessions to understand and proceed with their job. Even when they acquire the necessary skills, during the first stages of implementation, they all need support to verify they are working properly. Also, gradually adopting the modules, not all at the same time helps a lot. Users become more familiar with the system, so other modules are adopted. If we move in one shot, failure is guaranteed.
Are you facing problems in collecting previous data that were stored in the previous adopted system?	This is the most challenging part, some structures were completely changed; however, the user doesn't know anything about this, so the hardest task is to do the right mapping between fields and tables to merge them at the right place. Unfortunately, the IT department ignores the business while the users ignore the development. Hence, the most important thing which was a plus in our case is the presence of a team who knows well the business (Engineering background) having programming skills.
Are you able to extract significant data easily?	Data can be exported in excel sheets and additional checking could be done especially at the early stages of implementation. (To make sure that the data results comply with the reports and documentation generated and this helped a lot.)

Table 16 Summary Results of Targeted Questions Continued

As a project manager, engineer: how do you find the following attributes?	**Summary of the results**
Are you able to follow up on your KPIs regularly and easily?	Several KPIs are checked regularly due to the availability of real-time interactive dashboards which helped a lot in the decision making
Are you able to compare the planned, actual, and projected work?	In our case, the baseline plan along with the updated schedule was directly linked through the primavera web to the database, while the real progress is collected daily using the system and mobile application. Hence, in a single compacted dashboard, the three curves are presented and followed up on daily basis.
Are you able to manage the work achieved/to be achieved on your site in a faster and easier way?	Due to the present workflow in the system, validation processes are being generated more smoothly and this helped us gain a lot of time.
Are your losses in the form of labor costs decreasing? /Are you able to keep track of your staff timesheets easily?	We were unable to track the labors regularly, we had always doubt that there is a missing cost in this area however now, we are adopting a new module that allowed us to take the attendance, by far faster than, how we used to do it and our job mainly belongs to do the required checking and verification. New technology is being used which is the face recognition machine that minimizes cheating also.
Are your losses in the form of equipment rental costs decreasing?	Due to the system, we can link and compare between the daily activities and the equipment used and keep track of the equipment, especially since in road construction we have a lot of heavy equipment.

Table 17 Summary Results of Targeted Questions Continued

As a project manager, engineer: how do you find the following attributes?	**Summary of the results**
Are your losses in the form of raw material decreasing?	Till now, we can monitor the deliveries on-site; however, we aim to add a stock module that can help us later on. But in our scenarios, we can proceed without a stock module since our stock in road construction in terms of raw material and other assets is not significant.
Are you controlling the expenses and respecting the budget specified?	Yes, due to this compact screen we can immediately track in case of additional expenses and verify it. Not only that, the validation rules and security within the system itself, alert the user that there is something wrong. However, we have to help the development team and provide them with any additional requirements to add it.
Are you avoiding conflicts with sub-contractors due to proper management?	Traceability provided by the system helped us a lot where everything is registered in the system. All the documents are scanned, and you can access them. Also, Interim payments certificates are easily generated and saved a lot of time.
Are you able to monitor project status across different locations in just a few clicks?	Operational dashboards are present that help us track quickly. In case we need extra details, there is a detailed sheet where we can navigate to and check them. And the interesting fact is we can access the data wherever we are in case we have access to the internet.
Are you able to monitor projects progress across different locations in just a few clicks?	The daily progress is recorded using a module with the ERP and a mobile app. Even if there is no internet connection on the app the data are stored and once connected (at the end of the day) the app is synced, and all the progress appears. To be accurate, we can control the daily progress at the end of each day.

Summary of the main results from the interviews

Category 1:

The client owns a small construction company in Ivory Coast, and he is following the daily work achieved on two different construction sites using google sheets. Project managers fill up the progress achieved on-site in a weekly manner. He meets twice per month with the accountant to check the suppliers' balance. Recently, he is facing several problems with some suppliers and the project managers. Suppliers provide invoices for some products, however; project managers do not approve them. Thus, the problem appears, and he can't judge who is right and who is not.

He wants to reduce the sources of errors by forcing the suppliers and project managers to sign on a unique system to solve this issue. His main need is a module that follows up the requests for purchases, purchase orders, and deliveries on site. He stressed his need for an accounting module following up this step, however; he would like to implement it at a later stage for some financial reasons.

Category 2:

The client has a large company located in France and he has worked in different locations: Lebanon, Morocco, France, Egypt, and Poland. His main interest is to collect data and get them ready for analysis in a faster manner. The work of the company expanded quickly but the follow-up is becoming less productive. The work of this company belongs in the consultancy field. A group of engineers makes sure that the work on-site is properly achieved and provides the clients with the required invoices based on

the real progress. They are searching for a solution that provides them with real data, on time while they are not physically present on-site all time.

They requested three major modules: logistics, procurement and accounting, and work progress.

Category 3:

The client has a large company in Ivory Coast. His company combines 8 different sub-companies. Two of them are specified in the construction field. The first one is a contracting company for road and infrastructure construction and the second one is for buildings.

This company has already an ERP system that tracks the purchases and deliveries on-site, however; the general manager doesn't have any idea about the real work progress, the actual balance (stock), the logistics including equipment's follow-up, fuel follow-up, and timesheet of the employees especially that in the road construction company equipments are rented for a long period, a lot of travels are done by the trucks, … so cheating might occur easily.

His main interest is to be provided by a daily report on the real production achieved on-site, a daily detailed report for fuel consumption, equipment working hours, and available items on site.

Category 4:

The client has a large-scale construction company that has several branches: Lebanon, Togo, Benin, and Italy. The Lebanon branch is a design and procurement office while the

others are contracting offices where the construction is being executed. They work specifically on road construction.

The main need of this client is to collect data in a unique database that fasten the process between different departments. He wants to allow the design team to follow up on the progress of the work even though they are not at the same location. He wants a cost control module to follow up on its work. The general manager also requested to include the tender and planning module in this system since these tasks are already being achieved. And thus, he could get more accurate results.

The client has a design office for roads and building construction. His office is in Beirut, Lebanon. His main interest is the follow-up of the daily timesheet of the employee, the affectation of their working hours by projects. Thus, he requested a timesheet module.

He wants to compare the actual cost of the design by the estimation done and provide its team with a solid base to provide accurate estimations.

Category 5:

The client has a large construction company located in Lebanon (main branch) and it has several branches abroad: Congo, Nigeria, Ghana, and Cameroon. He requested a cost control module.

He wants to force the collection of data regarding raw materials (utilization and stock), personal and labor, equipment, and consumables (fuel).

4.2. ANALYSIS

4.2.1. Framework

The user activity varied among different modules, however; the modules that are used the most, based on the survey results, respectively work progress module (96.55 %), Budgeting, site operations, and inventory management modules (82.76%), Procurement and Document Control modules (75.86%), Accounting module (68.97%), Planning and scheduling module (58.62%), and Tendering module (51.72%). The usage of the modules confirms that their integration in construction companies is tangible. In addition to the results concluded by the literature stating the gaps among different modules (Hewavitharana & Perera, 2019) and the importance of implanting the ERP system in different stages (HADIDI, ASSAF , & ALKHIAMI, 2016), it is stated by the latter that the first three modules to be implemented in construction companies are inventory management, procurement, and accounting modules.

There are several differences between the type of construction companies. Some required data to be collected differ whether the company is constructing a road or a building.

In road construction companies' tasks to be achieved are most likely to be repetitive while building construction companies have a huge number of activities even in a typical structure. And a lot of variation orders might occur which also requires document control and follow-up.

In road construction companies, a huge number of heavy equipment must be followed up and managed in terms of transportation, fuel consumption, and maintenance while

another challenge is encountered in building construction companies, where stock management is required.

In road construction companies, daily reports require extra effort in terms of monitoring the activities that occur on-site. Moreover, quantities take-off is more challenging. However, in building construction companies' daily reports and take-off quantities are easier to be achieved.

In road construction companies, the control of every delivery on site is critical since cheating can be achieved easily, especially since several trucks reach the site at the same time, in different locations. However, building construction companies require another type of control for the tools and stock. Nevertheless, both need to monitor the attendance of the laborers.

These differences provide different needs in terms of treatment, requirements, and modules.

Both require a budgeting module.

Building structures could not bypass a **document control module** to track any amendment and all the drawings, submittals, approvals, …

This is **not the case for road construction companies**.

Both require a procurement and delivery module.

The procurement department in building construction companies has a lot of challenges and must be aware of all the details needed. All the purchases must be delivered on time.

It has a lot of items to be ordered ahead of time and the deliveries must be linked to a **stock management module**.

However, in road construction companies' deliveries must be linked to **the activities** that are being achieved and to **the equipment** (trucks) that reach the site and leave it.

Both require a timesheet module.

The labor cost highly affects the total cost of the construction process. And a lot of money could be wasted in case of a bad follow-up and tracking. In road construction projects different challenges are present compared to building construction projects. A base is always close to the site in building construction projects and check-ins and out are monitored easier than in a road construction project.

Thus, in the construction field, the ERP systems are unique based on the work achieved by the company.

This complements the literature in terms of the uniqueness of construction companies (Luo & Strong, 2004) and the importance of customization based on the present requirements and needs (Dilakshan, Disaratna, & Silva, 2018). After achieving technical observations and a large number of meetings with engineers in the construction field, and taking into consideration the differences among construction companies' types, a framework suggesting the minimum required module adapt in roads and infrastructure engineering companies is presented below along with the order of integration of these systems.

Figure 4 presents the framework suggested divide in three phases.

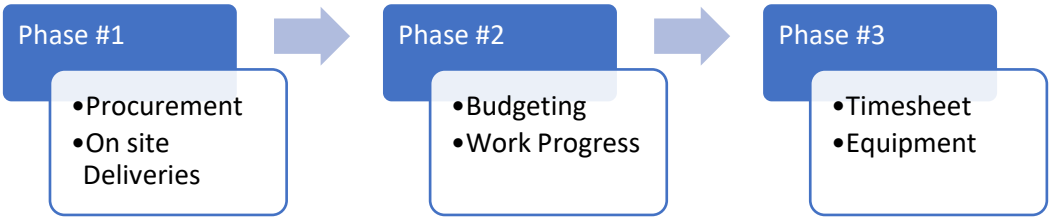

Figure 4 Suggested Framework

Procurement and On-site Delivery Modules:

PMBOK:

"Materials represent a major expense in construction, so minimizing procurement and purchase costs presents important opportunities for reducing costs."

Project managers send their requests to the procurement department where a request for quotation and purchase orders are done. The procurement manager searches for the required material to be purchased for all the company's projects while aiming to get the best offer and reach the most cost-effective and appropriate product. This leader must have several skills such as analytical thinking, negotiation skills, communication skills, and most importantly, knowledge of the construction and materials to understand the overall figure. The more this task is properly handled, the more the project becomes cost-effective and profitable. The job does not end at the level of the orders, however; the procurement management team must ensure that the deliveries are achieved on time and within the specifications listed: the procurement department should be aware of the deadlines and ensure that the purchases will not delay any work. In the construction field, most of the time, the purchase orders are done from the offices while the deliveries are on site. Also, many constraints could appear within this process, a unique supplier might not have all the quantity needed, a substitute might be available, or even a better price might be taken by reserving a certain quantity, … Hence, good communication must be achieved within the two teams (on-site and procurement department) to make sure that the order has reached the site with the requested quantities and quality.

Three main pillars contribute to this process:

1. The project's planning and required material
2. The history of similar material previously purchased
3. The on-site deliveries

This module is described in figure 5.

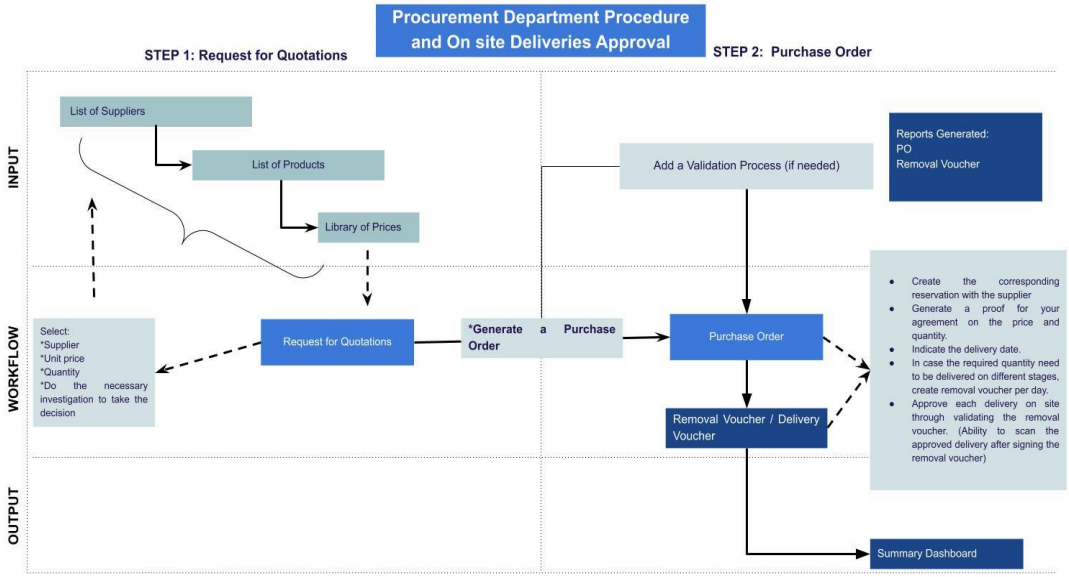

Figure 5 Procurement & Delivery Module

Budgeting and Work Progress Modules:

Comparing the projected and actual progress is very critical to measure some key performance indicators such as schedule performance indicator and cost performance indicator.

A suitable budget makes it feasible to get a good cost estimation of the project. Also, a list of priority results for each project leads to better decisions making and more effective project management.

Collecting regular data from the site helps measure the progress more accurately and allows the project manager to detect whether the project is behind schedule or not.

Figures 6 and 7 show respectively a plan for the budget and work progress modules.

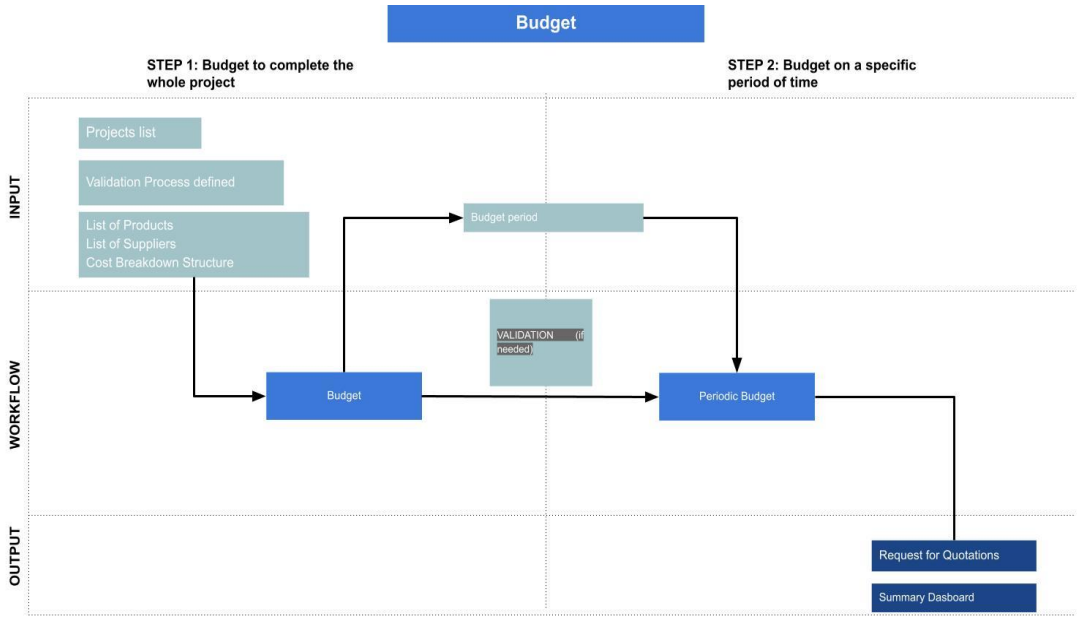

Figure 7 Budget Module

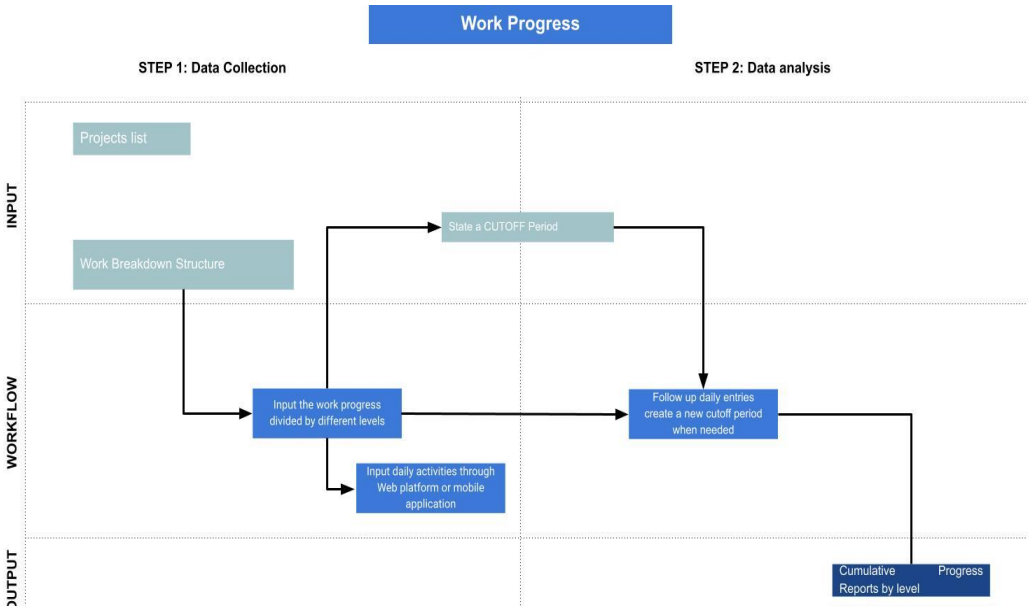

Figure 6 Work Progress Module

Site Operations: Time sheet and Equipment follow-up Modules:

Registering the attendees on-site, on large-scale projects need to be well monitored to minimize any extra costs due to personnel. It also helps track the lack of personnel in specific areas. Most importantly this work will be achieved in real-time.

Moreover, due to mismanagement among several projects, an operation on site might be delayed or stopped due to a lack of equipment. Hence, it is very important to track all the equipment and make sure this equipment will reach the site on time. Also, collecting the working hours or working kilometers for each piece of equipment saves a lot of costs.

As a result, having modules that can track on-site operations is very important and optimize the cost.

The previously described modules are presented in figures 8 and 9.

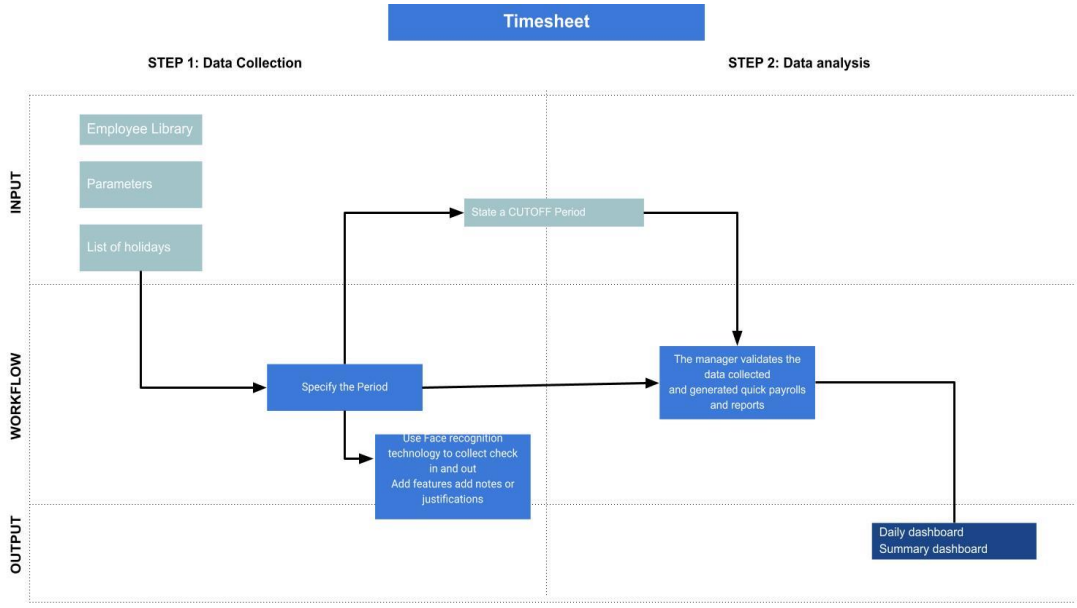

Figure 8 Timesheet Module

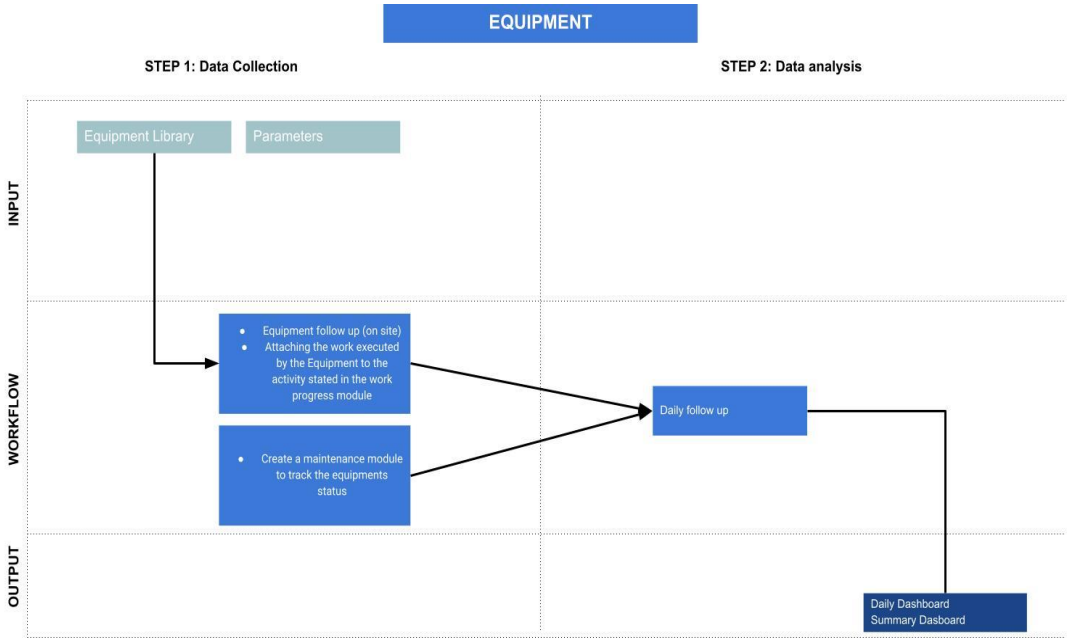

Figure 9 Equipment Follow-up Module

4.2.2. Benefits of a customized ERP in the construction industry

For all the attributes listed, the largest percentages belong to Good and Excellent ratings.

Around 52% of the excellent rating is given to workflow attributes that comply with the results listed by Shi and Halpin (2003) and Lee et al. (2004) regarding the advantages in terms of workflow and good communication between different departments.

In terms of flexibility and performance, 42.38 % and 44.83% respectively are given to the excellent rating which also complements the results of Ahmad et al. (2003).

Additionally, the previously listed attributes have the highest percentages in ratings in terms of “Excellent”.

Moreover, traceability of each task, uploading and downloading documents, monitoring daily activities, and optimizing the usage of resources are pointed out by a group of

project managers and engineers currently using ERP systems. These results are confirmed by Shi and Halpin (2003), Ahmed et al. (2003), and Lee et al. (2004).

However, in this research, investigating the correlation between two different attributes (flexibility and workflow) on Documentation and Reporting and Mobile Application is a point of interest.

The results were analyzed using SPSS. The following table 18 shows the normality test to decide how to proceed in the analysis.

Table 18 Tests of Normality (1)

	Kolmogorov-Smirnov[a]			00Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Ease of Use	.274	29	.000	.822	29	.000
Flexibility	.248	29	.000	.812	29	.000
Stability	.344	29	.000	.763	29	.000
Performance	.282	29	.000	.778	29	.000
Workflow	.321	29	.000	.748	29	.000
Security	.386	29	.000	.664	29	.000
Documentatin and Reporting	.345	29	.000	.726	29	.000
Mobile Application	.226	29	.001	.843	29	.001
Less Work to Do	.452	29	.000	.561	29	.000
Strict Measures to adopt ERP	.501	29	.000	.460	29	.000
Relibale Upgrade	.527	29	.000	.354	29	.000
Continuous Support	.536	29	.000	.281	29	.000
a. Lilliefors Significance Correction						

First, Shapiro-Wilk is considered since the sample data is less than 100.

Second, the significance is less than 0.05, then all the variables are statistically significant and hence, the data are not normally distributed.

To validate that the data are not normally distributed, log10 of the values is computed and the results are presented in table 19 below. And thus, ordinal regression analysis is performed.

Table 19 Tests of Normality (2)

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
EOU	.317	29	.000	.783	29	.000
FLX	.276	29	.000	.776	29	.000
STB	.386	29	.000	.697	29	.000
PRF	.270	29	.000	.768	29	.000
WF	.312	29	.000	.739	29	.000
SCR	.368	29	.000	.622	29	.000
DAR	.335	29	.000	.717	29	.000
MOB	.270	29	.000	.818	29	.000

How do Workflow and Flexibility affect Documentation and Reporting?

Table 20 Model Fitting Information (1)

Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Intercept Only	35.041			
Final	14.834	20.207	2	.000
Link function: Logit.				

Table 20 shows that the model fits the data very well since the data are statistically significant. This result is complemented by Person and Deviance results as shown in table 21 below.

Table 21 Goodness-of-Fit (1)

	Chi-Square	df	Sig.
Pearson	5.725	12	.929 >0.05
Deviance	4.973	12	.959 >0.05
Link function: Logit.			

Table 22 Pseudo R-Square (1)

Cox and Snell	.502
Nagelkerke	.606
McFadden	.396
Link function: Logit.	

Around 60% changes in documentation and reporting as a result of Workflow and Flexibility.

This is presented by highlighted value in table 22.

Table 23 Test of Parallel Lines (1)

Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Null Hypothesis	14.834			
General	13.243	1.591	2	.451>0.05
The null hypothesis states that the location parameters (slope coefficients) are the same across response categories.				
a. Link function: Logit.				

Validating that the assumption of proportional odds is not being violated is present in table 23. The value is not statistically significant which validates the assumption.

Finally, table 24 shows the parameter estimates corresponding to the effect of the two independent variable: flexibility and workflow on documentation and reporting.

Table 24 Parameter Estimate (1)

Parameter Estimates											
Parameter		B	Std. Error	95% Wald Confidence Interval		Hypothesis Test			Exp(B)	95% Wald Confidence Interval for Exp(B)	
				Lower	Upper	Wald Chi-Square	df	Sig.		Lower	Upper
Threshold	[Documentation and Reporting =3]	8.746	3.2088	2.457	15.035	7.429	1	.006	6285.111	11.668	3385685.710
	[Documentation and Reporting =4]	13.476	4.2440	5.158	21.794	10.082	1	.001	711932.922	173.766	2916845497.913
Flexibility		1.743	.8861	.006	3.479	3.868	1	.049	5.713	1.006	32.441
Workflow		1.439	.8390	-.205	3.083	2.941	1	.086	4.216	.814	21.828
(Scale)		1[a]									
Dependent Variable: Documentation and Reporting Model: (Threshold), Flexibility, Workflow											
a. Fixed at the displayed value.											

Flexibility is statistically significant, but the workflow is not statistically significant

Flexibility is a statistically significant positive predictor of documentation and reporting.

For every 1 unit increase in flexibility, there is a predicted increase of 1.743 in the log odds (probability of success/probability of failure) of being at a higher level on documentation and reporting.

The Exp(B) column contains odds ratios reflecting the multiplicative change in the odds of being in a higher category on the dependent variable for every one-unit increase on the independent variable, holding the remaining independent variables constant.

The odds ratio indicates that the odds of being in a higher level on documentation and reporting increases by a factor of 5.713 for every 1 unit increase in flexibility.

Table 25 Correlations (1)

Correlations					
			Documentation and Reporting	Workflow	Flexibility
Spearman's rho	Documentation and Reporting	Correlation Coefficient	1.000	.674**	.621**
		Sig. (2-tailed)	.	.000	.000
		N	29	29	29
	Workflow	Correlation Coefficient	.674**	1.000	.679**
		Sig. (2-tailed)	.000	.	.000
		N	29	29	29
	Flexibility	Correlation Coefficient	.621**	.679**	1.000
		Sig. (2-tailed)	.000	.000	.
		N	29	29	29
**. Correlation is significant at the 0.01 level (2-tailed).					

Workflow and Flexibility are statistically significant and have a good correlation respectively between documentation and Reporting. This result is shown in table 25.

How do workflow and Flexibility affect Mobile Applications?

Table 26 Model Fitting Information (2)

Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Intercept Only	49.092			
Final	31.217	17.874	2	.000
Link function: Logit.				

The model fits the data very well since the data are statistically significant as shown in table 26. This result is complemented by Person and Deviance results presented in table 27.

Table 27 Goodness-of-Fit (2)

	Chi-Square	df	Sig.
Pearson	22.527	19	.259
Deviance	21.904	19	.289
Link function: Logit.			

Table 28 shows that around 51% changes in Mobile Applications as a result of Workflow and Flexibility. While table 29 shows that the assumption of proportional odds is not being violated.

Table 28 Pseudo R-Square (2)

Cox and Snell	.460
Nagelkerke	.509
McFadden	.262
Link function: Logit.	

Table 29 Test of Parallel Lines (2)

Model	-2 Log-Likelihood	Chi-Square	df	Sig.
Null Hypothesis	31.217			
General	25.438	5.779	4	.216>0.05
The null hypothesis states that the location parameters (slope coefficients) are the same across response categories.				

Table 30 Parameter Estimates (2)

Parameter Estimates											
Parameter		B	Std. Error	95% Wald Confidence Interval		Hypothesis Test			Exp(B)	95% Wald Confidence Interval for Exp(B)	
				Lower	Upper	Wald Chi-Square	df	Sig.		Lower	Upper
Threshold	[Mobile Application=2]	5.722	2.6705	.488	10.956	4.591	1	.032	305.473	1.629	57296.026
	[Mobile Application=3]	8.522	2.7985	3.037	14.006	9.272	1	.002	5021.840	20.835	1210395.350
	[Mobile Application=4]	11.613	3.3557	5.036	18.190	11.975	1	.001	110490.578	153.788	79383174.929
Workflow		2.036	.8196	.430	3.643	6.173	1	.013	7.663	1.537	38.202
Flexibility		.386	.6692	-.925	1.698	.333	1	.564	1.472	.396	5.464
(Scale)		1[a]									
Dependent Variable: Mobile Application Model: (Threshold), Workflow, Flexibility											
a. Fixed at the displayed value.											

Workflow is statistically significant, but the flexibility is not statistically significant Workflow is a statistically significant positive predictor of mobile applications.

For every 1 unit increase in workflow, there is a predicted increase of 2.036 in the log odds of being at a higher level on mobile applications.

The Exp(B) column contains odds ratios reflecting the multiplicative change in the odds of being in a higher category on the dependent variable for every one-unit increase on the independent variable, holding the remaining independent variables constant.

The odds ratio indicates that the odds of being in a higher level on mobile application increases by a factor of 7.663 for every 1 unit increase in workflow.

These results are presented in table 30.

Workflow and Flexibility are statistically significant and have a good correlation respectively between Mobile Applications which is seen in table 31.

Table 31 Correlations (2)

Correlations					
			Mobile Application	Flexibility	Workflow
Spearman's rho	Mobile Application	Correlation Coefficient	1.000	.541**	.738**
		Sig. (2-tailed)	.	.002	.000
		N	29	29	29
	Flexibility	Correlation Coefficient	.541**	1.000	.679**
		Sig. (2-tailed)	.002	.	.000
		N	29	29	29
	Workflow	Correlation Coefficient	.738**	.679**	1.000
		Sig. (2-tailed)	.000	.000	.
		N	29	29	29
**. Correlation is significant at the 0.01 level (2-tailed).					

4.2.3. Reporting-Interactive Dashboard

Summarizing the answers of the project managers and engineers, several benefits are also gained through using the CERP system. These benefits belong to extracting data very easily in excel format, pdf reports, and through having a compact interactive screen showing the required information depending on which category of data is needed. Such reporting procedures helped them a lot during implementation to confirm that the data extracted from the system are reliable and then helped them in managerial work. Key Performance Indicators were added to the dashboards as requested and they are followed up regularly.

Some dashboards presented a comparison between the budget and actual expenses which includes several important indicators. Additionally, alerts can appear on the dashboard based on some pre-defined threshold, as requested, which fastens the analysis and decision making.

Also, having a compact screen that compares between the baseline, the actual and the projected work has a very important impact on project status and alerts. Hence, using such screens helps a lot in managerial tasks and follow-up as mentioned by (Hamzeh, et al., 2020).

Projects managers affirmed that the usage of interactive dashboards in each department is a must. They stressed the point that the point of interest of each manager differs from one another and thus the interactive dashboard is built upon its need.

For example, a general manager needs to see the status of the project on a macro view and in case he needs to dig into the details he can access the detailed dashboard that is being used by project managers.

They also pointed out the importance of good data collection. All the data collected appears on the dashboard and hence, they can track them especially during the implementation phase they can notice a wrong data entry and follow it very quickly.

4.2.4. Encountered challenges in the implementation of the system

Companies in developed countries are forced to follow strict legislation while companies in developing countries tend to bypass the laws and escape from taxes. Thus, recording all data might not be convenient for companies in developing countries which is not the case in developed countries. Moreover, a minimum level of labor competency is required in developed countries while laborers in developing countries might be uneducated and they may not receive the proper education and training needed which is not the case in

developed counties. Thus, difficulties in teaching manpower are most likely to be encountered in developing countries which is also validated by (Windapo, 2013). Without ignoring the importance of having good training sessions to reach successful implementation as resulted by Fleming et al. (2007). Project managers and engineers pointed out the importance of continuous support during the implementation. Additionally, commissioning takes extreme scenarios which will not be able to be achieved if proper follow-up is being achieved through an ERP system, hence; the usage of a system that tracks the workflow will not be encouraged. Moreover, technical problems as developed by Luo et al. (2004) such as connection problems are most likely to be found in developing countries which is not a task to worry about in developed countries. As a result, different challenges are faced through the implementation of an ERP system in a country. Regardless that Jingsheng Shi and Halpin, (2003), Nitithamyong and Skibniewski, (2004), and Dilakshan et al. (2018) agreed on the uniqueness of construction companies, the customization of the system will release this constraint which is also advised by Dilakshan et al. (2018). Finally, and in opposition to Shi and Halpin (2003) that indicated that it is hard to track the earned value, % completion, project progress, scheduling, budgeting, procurement process, and reporting, these constraints are released through adopting the previously suggested modules. However, a noticeable challenge is faced by the engineers and managers regarding the data migration that the company has and uses before having the ERP. They elaborated on the importance of having a team that knows both development and business to achieve a good migration from any old system to a new one. They agreed that the cooperation of the executive team with the development and integration team is a must and sometimes

unless there is strict measure from the CEO to do so, the employee tries to avoid the cooperation to develop a new system that complements the results of Fleming et al. (2007) and Kwak et al.(2011).

5. COST

An approximation of the cost is presented in tables 32 till 38 presented below. The strategy adopted considered the minimum modules suggested as divided into three phases. The minimum required interfaces within each module are considered along with some features such as export of the data in excel template, UX components for a mobile application form, reporting in terms of interactive dashboards using Microsoft Powerbi. These costs assumed the overhead cost needed to develop these interfaces. Besides some lifetime license fees along with annual fees are presented which are elaborated based on the usage of MS SQL SERVER as the base of data storage, a dedicated cloud server, Microsoft power bi license for interactive dashboards, and alpha anywhere for the web interfaces. While the UX components are presented on Appsheet which only requires the presence of a Gsuite domain. Finally, the training required is considered. However, in case additional practice sessions are needed then the extra cost must be added. This cost section varies a lot in case a full-time implementing team is required for a specific period (6 months).

Table 32 Development and Deployment Cost

	Construction ERP System (Minimum required Modules)				
		Quantity	**Unit**	**Unit Price**	**Price**
1- Development and Deployment (Web Platfform & Database)					
Phase 1	User Interface Grids - Editable & Read only - List of Suppliers	**1**	**Lump sum**	900	900
	User Interface Grids - Editable & Read only - List of Products	**1**	**Lump sum**	900	900
	User Interface Grids - (Parent - Child) Editable & Read only - Linking Suppliers to products and prices.	**1**	**Lump sum**	1,200	1,200
	User PLC Interface Grids (Parent & Child) - Editable -Request for Quotation	**1**	**Lump sum**	1,200	1,200
	User PLC Interface Grids (Parent & Child) - Editable -Purchase Orders	**1**	**Lump sum**	1,200	1,200
	User PLC Interface Grids (Parent & Child) - Editable -Removal Orders	**1**	**Lump sum**	1,200	1,200
	User PLC Interface Grids (Parent & Child) - Editable -On site deliveries	**1**	**Lump sum**	1,200	1,200
	UX Component (Mobile Application) -On site Deliveries	**1**	**Lump sum**	300	300
Phase 2	User Interface Grids - Editable & Read only - List of Projects	**1**	**Lump sum**	900	900
	User Interface Grids - Editable & Read only - List of CBS	**1**	**Lump sum**	900	900
	User PLC Interface Grids (Parent & Child) - Editable -Budget list	**1**	**Lump sum**	1,200	1,200
	User PLC Interface Grids (Parent & Child) - Editable -Periodic Budget list	**1**	**Lump sum**	1,200	1,200
	User PLC Interface Grids (Parent & Child) - Editable -Work Progress	**4**	**Lump sum**	1,200	4,800
	UX Component (Mobile Application) -Work Progress	**1**	**Lump sum**	300	300
Phase 3	User Interface Grids - Editable & Read only - List of Employee	**1**	**Lump sum**	900	900
	User Interface Grids - Editable & Read only - List of Holidays	**1**	**Lump sum**	900	900
	User PLC Interface Grids (Parent & Child) - Editable -Timesheet	**1**	**Lump sum**	1,200	1,200
	Face Recongnition Machine (including Installation and	**1**	**Lump sum**	5,000	5,000
	User Interface Grids - Editable & Read only - List of Equipments	**1**	**Lump sum**	900	900
	User PLC Interface Grids (Parent & Child) - Editable -Equipment	**2**	**Lump sum**	1,200	2,400
	UX Component (Mobile Application) -follow up, activities	**2**	**Lump sum**	300	600
		TOTAL (USD)			**29,300**

Table 33 Functionalities Cost

		Quantity	**Unit**	**Unit Price**	**Price**
2- Functionalities (Export) MS Excel					
	End User Interface				
Phase 1	Export Functionalities Towards Excel (Xls Version)	**7**	**Lump sum**	1,200	8,400
Phase	Export Functionalities Towards Excel (Xls Version)	**8**	**Lump sum**	1,200	9,600
	Import Functionalities From Excel (Xls Version)	**4**	**Lump sum**	1,200	4,800
Phase	Export Functionalities Towards Excel (Xls Version)	**4**	**Lump sum**	1,200	4,800
	Import Functionalities From Excel (Xls Version)	**1**	**Lump sum**	1,200	1,200
		TOTAL (USD)			**28,800**

Table 34 Interactive Dashboards Cost

		Quantity	Unit	Unit Price	Price
3- Interactive Dashboards (Microsoft Power BI)					
	End User Interface				
Phase 1	Daily Followup Dashboard (Interactive Daily deliveries on site view compared to requested deliveries and PO real time data)	**1**	**Lump sum**	650	650
Phase 2	Operation Dashboard Comparing the Budget to the Expenses and KPIs	**1**	**Lump sum**	950	950
	Baseline/Actual/Forecast Dashboard	**1**	**Lump sum**	1,100	1,100
Phase 3	Daily and Summary Dashboards for employee and labor attendance	**1**	**Lump sum**	650	650
	Daily and Summary Dashboards for Equipment Followup	**1**	**Lump sum**	650	650
		TOTAL (USD)			**4,000**

Table 35 Implementation Cost

4- Implementation of the Platform (Training and Documentation)					
4.1	**Users Training (Web Connexion, Input Data, Application Usage)**	**40**	**Users**	13	520
4.2	**Documentation and User Manual**	**1**	**Lump sum**	150	150
		TOTAL (USD)			**670**

Table 36 Annual Fees

		Quantity	Unit	Unit Price	Price
5- Annual Hosting and License Fees (Includes Installation and Technical Support fees)					
5.1	**Dedicated Cloud Server : 1x Intel® Xeon® E5 1410 v2 Include Official MS Window Server 2016 License RAM:96 Go DDR3 ECC 2x 500 Go SSD RPN 100 Mbit/s Up to 1 Gbit/s (Business)**	**12**	**Monthly**	360	4,320
5.2	**Business Intelligence Dashboard Microsoft Power BI, Business Analytic Dashboard (Incl. mails and web hosting domain at Google G Suite)**	**240**	**User x Month**	9	2,160
5.3	**Project Management ERP System - Web Browser Solution (Alpha Anywhere Inc)**	**1**	**Lump sum**	4,995	4,995
		TOTAL (USD)			**11,475**

Table 37 Lifetime License and Server

		Quantity	Unit	Unit Price	Price
6- MS Server + MS SQL Server Standard Edition License Fee (Lifetime)					
6.1	**License Window Server 2016 or Above Standard**	**1**	**Lump sum**	799	799
6.2	**MS SQL Server Standard Edition - Core data management and business intelligence capabilities for non-critical workloads with minimal IT resources.**	**1**	**Lump sum**	3,379	3,379
		TOTAL (USD)			**4,178**

Table 38 Cost per Phase

	Cost (USD)
Phase 1	17,150
Phase 2	-
Phase 3	-
Implementation	670
Annual Fees	11,475
Lifetime License	4,178
Total (USD)	33,473

	Cost (USD)
Phase 1	17,150
Phase 2	25,750
Phase 3	-
Implementation	670
Annual Fees	11,475
Lifetime License	4,178
Total (USD)	59,223

	Cost (USD)
Phase 1	17,150
Phase 2	25,750
Phase 3	19,200
Implementation	670
Annual Fees	11,475
Lifetime License	4,178
Total (USD)	78,423

6. LIMITATIONS

This study has elaborated on a proposed framework for the minimum required modules to adapt in roads and infrastructure construction companies which was not addressed in the previous studies. Further, the impact of workflow and flexibility on documentation & reporting and mobile applications is shown. The benefits and challenges especially in developing countries are presented along with the importance of using interactive dashboards. However, some limitations could be extracted and are advised to be considered in future studies. First, the development period required for the system is not taken into consideration which might impact the revenue of the company during this phase. Second, the survey sample is suggested to be incremented and to tackle engineers and managers from different disciplines. Third, the company size and the type of work achieved by the company (consultancy, engineering, …) need to be addressed and taken into consideration.

7. CONCLUSIONS

To conclude, this research is important to be achieved since managing construction companies remains a challenge particularly in developing countries. Moreover, optimizing the resource allocation, cost, and time are the key elements of a good strategy design, but having the necessary tools to manage these resources through different departments and tasks will guide any project to success. Hence, the role of ERP systems arises and the need for specific modules to be implemented will be asked. Choosing the best framework to adopt and to prepare your company for the obstacles that might be faced will facilitate the integration of these systems. The outcome of this research presents a framework composed of three main phases including respectively the following modules: procurement, delivery, budget, work progress, timesheet, and equipment. These results are observed from several meetings with experienced people in the field, a survey distributed among users, and technical observations. The study also presents the challenges faced in a developing country such as legislation, labor competency, technological problems, and the need for customization. Regardless of the listed challenges, several benefits appear from the usage of ERP systems. These benefits are elaborated based on the survey's results. Implementing ERP systems increases revenues in the long term since it saves time, elaborates on quick documentation and reporting techniques, minimizes cost, reduces potential delays, empowers workflow and flexibility, and improves decision making. Complementing the system with interactive dashboards is highly recommended since such compacted screens can provide a large amount of data in one screen which facilitates decision making and management. Finally, an approximated cost of $78,423 for the minimum required modules to adopt is shown.

The cost is approximated by phases. However, further consideration might be taken in terms of cost, implementation time, size of the company, and the type of work achieved by the company.

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9. Appendix A: Survey

Table 39 Survey ; https://forms.gle/XDHtRjssrtMJDmSf9

Have you ever used and ERP system? (Even if it includes only one module) (Yes/No)				
When did you start using an ERP System?Specify the year.				
As a Project Manager/Manager: how do you rate the following attributes ?	**Excellent**	**Good**	**Fair**	**Poor**
Ease of Use				
Flexibility				
Stability				
Performance				
Workflow				
Security				
Documentation and Reporting				
Mobile Application				
As a Project Manager/Manager:	**Yes**		**No**	
Do you have less work to do than what you were used to accomplish before adopting the new ERP?				
Are you forced to follow up and work on the new system by their managers?				
Are you receiving a Reliable Upgrade (improving processes previously adopted)?				
Are you receiving on time, continious support?				

10. Appendix B: Questions

Table 40 Questions

As a project manager, engineer: how do you find the following attributes ?
Are you facing obstacles in convincing the users to adapt to the new customized system?
Are you facing obstacles while teaching your staff to use the new cutomized ERP using new techniques: Tablets, Application through web,...?
Are you facing problems in collecting previous data that were stored in the presvious adopted system?
Are you able to extract significant data easily?
Are you able to follow up your kpi's regularly and easily?
Are you able to compare between the plannned, actual and projected work?
Are you able to manage the work achieved/to be achieved on your site in a faster and easier way?
Are your losses in the form of labor cost decreasing?
Are your losses in the form of equipment rental costs decreasing?
Are your losses in the form of raw material decreasing?
Are you controlling the expenses and respecting the budget specified?
Are you avoiding confilicts with sub contractors due to proper management?
Are you able to estimate properly the required raw materials, designs, labors,...?
Are you able to monitor project status acroos different locations in just few clicks?
Are you able to monitor projects progress acroos diffrent location in just few clicks?
Are you able to keep track of your stock on site easily?
Are you able to keep track of your staff timesheets easily?