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Action Research: the Use of Enterprise Resource Planning System in Construction Engineering and Project Management

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Abstract: ***Although information communication technology (ICT) is long regard as very useful tool in today's construction engineering and project management environment, organizations must not only operate based upon its original setting, but also requires on-going observation, additional features and fine-tuning actions before the desirable outcome can be achieved. However, it is a very common phenomenon that organizations purchase the licensed "off-the-shelf-software" package and customize it to suit their own business need. Due to the incapability of such software and inefficient customization, the possible result is making that ICT tool not user-friendly and sometimes the whole system becomes obsolete.***

The purpose of this paper is to review and report those actions taken (between February 2006 and December 2010) by a construction organization to enhance the performance of its Enterprise Resource Planning (ERP) system launched in December 2002. Such actions include: improving data inputting method; removing the transition bottleneck; introducing crystallization function; revising the organization's "Delegation and Limits of Authority"; publishing the "League Table" amongst users; integrating the 3D Modeling into the system and upgrading hardware.

Whilst the ultimate goals of such system are well beyond the time limit of this research study, an obvious interim result, achieved by this case studied organization, was winning a landmark project worth US$500 million after the ERP system was functioned properly and effectively. Their experience and success becomes an exemplar which can be borrowed by those companies, from managerial perspectives and as a roadmap, planning to adopt information technology (IT) strategy and use ICT tool in the construction engineering and project management framework.

Singapore, where public housing provisions have been a major concern of their citizens as the building stock gets older.

Keywords: Project Management, Enterprise Resource Planning (ERP), Information Communication Technology (ICT), Construction Management

I. INTRODUCTION

When an organization decides to adopt the IT strategy and use an ICT tool to assist its management, it is not uncommon only to purchase a commercial off-the-shelf software (COTSS) package and entirely rely on its original setting. Many research studies (Yakimovich et al., 1999, McKinney, 1999, Fui-Hoon Nah et al., 2003, Brehm et al., 2001) have identified the adverse implications of using COTSSs without proper preparation and transition. These authors share the similar opinions that these products create software integration problems which hamper their effectiveness and have to modify in various ways to meet essential needs. Sometimes, consultant specialists will be deployed to work with its own IT team and customized the software to suit the company unique requirements. However, this resultant ICT tool is still operated based upon its original features and may not be user-friendly. Without long-term tactical ongoing observations, controlling measures, monitoring aids, adding features and fine-tuning actions to such tool, the perceived goals and desirable outcomes are hardly achieved. When users do not satisfy with that tool; the possible result is making such tool becomes obsolete.

Liu et al. (2002) state that many companies suffer from costly IT investment failures, one of the common reasons for these failures is the new ICT system's compatibility to the existing system, training, and technology mergers. This kind of IT strategy is not good enough and proved to be fail. Due to the incapability and inefficiency of the software and customization, therefore, the successful IT strategy must not be run without adopting adequate follow up actions.

This paper is a case study of a Hong Kong construction organization about using ERP system to assist its construction engineering and project management business. Prior to the investigation of the actions improving the performance of the ERP system, the first stage of the research project is extensive reading to diagnoses the problems and the second stage is exploratory surveys to find out the root problem areas. Then, stage three (i.e. the scope of this paper) is to describe and conclude the plan to improve the

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This paper is the about those implemented actions and situation. the observed interventions, in two cycles, that have been taken place from 2002 to 2010. The lesson learnt can be borrowed to demonstrate how organizations can plan the IT strategy in assisting construction engineering and project management.

The structure of this paper is as follows. Firstly, literature is reviewed which forms the basis underpinning the research study. It follows by a brief of the research approach and the context of action research. Interim results of the actions taken, limitation and recommendation for further research are also discussed. This paper ends with the conclusions.

II. Literature Review

Previous research studies and literatures are crucial for new research work because those studies and literatures demonstrate a relevant area of knowledge and identify a gap in theory or practice worthy of study. In the following context, literatures underpin the basis of this paper are discussed.

A. Propensity of Using ICT Tool in Construction Engineering and Project Management

It becomes popular for the construction engineering and project management companies to use the ICT tool to enhance the organizational efficiency. Many research studies have investigated this subject and various works in different countries have been conducted in respect of IT application.

In USA, Liu et al. (2002) study the potential applications of IT for engineering and construction collaboration. The authors concluded that the advances in IT have created new ways of performing engineering and construction tasks for a project. These IT advances allow project participants to collaborate without the barriers of time and distance. In Australia, (Peansupap, 2004)'s thesis advocated that emerging ICT introduced various opportunities for improving communication and improved many construction processes at each project phase. Thus, the perceived ICT benefits have motivated numerous construction organizations to adopt and invest in IT.

In Korea, Seok (2002) conducts a research of using IT to assist project management information system, and agreed that IT helps construction team not only be able to make precise analysis and decision-making, but also record the information for future reference during claims and making estimates on similar projects. Jinho et al. (2011) analyze the information transference mechanism of large-scale construction projects by input/output information and the relation of players and studied the development process for information flow retrieval system, by the "Integration DEFinition 0" and "Entity Relationship Diagram" technologies. In Singapore, Chee et al. (2008) analyze the high potential and economic opportunities of the ASEAN construction market and designed an IT tools, "the visual analysis using computer-based cartography" to strategically analyze those construction related activities. Yusuf et al. (2008) evaluate the use of IT in the Malaysian construction industry and concluded that the diffusion of information technologies was rapid. The state of use of IT applications was gradually increasing, which meant most companies perceived the use of IT's efficiency and saving time and costs.

In Hong Kong, according to CIRC (2001), IT will help to improve construction efficiency through better information flow among project participants, improved design capability and enhanced project logistics management.

Benefits of adopting IT strategies and using ICT tools in construction engineering and project management are obvious, and one of the useful tools is the ERP system.

B. Use of Enterprise Resource Planning (ERP) System

In the construction engineering arena and project managment environmement, the adoption of IT and ICT tool will help to enhance competitive advantage (Peansupap, 2004). According to Maruyama et al. (2000), more advanced solution to forecast and ensure the project, the virtual and real-field construction management system had been introduced to evaluate the productivity and safety as virtual simulations Therefore, a well-developed ERP system can deliver greater job efficiency. Through automation the construction project was able to provide important project information to all stakeholders online, which included project status and financial information.

According to Deng et al. (2001), a survey revealed the internet-based or internet related ICT solutions were reported to be very useful in the construction industry. ERP system is an internet related software system and many organizations use this system as their ICT backbone. Al-Mashari et al. (2003) describe ERP system can be customized from standard integrated software applications that facilitate IT coordination in control aspects of management and other operational facets. ERP systems can also integrate numerous project management control processes such as cost and time management. It links to groupware that allows communication and coordination, joint problem solving and recording transaction histories. In this way it is capable of facilitating groups of people to solve specific problems and through the audit trail of data to trace the evolution of decision-making. Therefore, ERP system is very suitable in the construction engineering project management.

C. Reasons for Improvement Actions

According to Brehm et al. (2001) field research has shown that many companies have had to modify ERP software in various ways to meet essential business needs. This suggests that ERP packages do not fit cleanly into the custom/off-the-shelf distinction. Somers et al. (2001) propose several steps for a successful ERP implementation, and suggest effective change

management system must be in place. Fui-Hoon Nah et al. (2003) identify eleven critical success factors, with underlying subfactors, for successful ERP implementation. The five most critical factors identified are top management support, project champion, ERP teamwork and composition, project management, and change management program and culture. Therefore, the best guarantee lies in involving necessary management to support changing needs and improvement options to the system.

Peslak et al. (2007) distinguish the existence of four distinct phases of ERP implementation, namely preparation and training, transition, performance and usefulness, and maintenance. The author find that the two significant phases which directly influenced preferred ERP use were preparation and training phase, and performance and usefulness phase. Usefulness is also related to performance. Perceived usefulness looks at productivity, job effectiveness, and ease of doing the job which could be argued as performance related variables. It reflects that usefulness of the system must be monitored after implementation and intervene with all necessary means. Vilpola (2008) state that an ERP system is implemented to increase the productivity and operational efficiency of companies. However, the implementation activities and changes within operational processes pose a temporary threat to productivity. Reported difficulties in implementation projects frequently relate to organisational and human-centred issues; like the ability and motivation of the organisation to accept the new ERP system.

Zhang et al.(2005) mention that when organization uses an ERP system, it should be integrated with the overall company's strategic plan. The authors also concluded that only few employees understood the function and effectiveness of an ERP system, and the top managers did not realize the objectives of an ERP system in each step of the whole circle, which eventually affected the efficiency of the system. Therefore, continuous improvement actions, including proper training and practising are required after the system is in operation.

Yakimovich et al. (1999) state that most COTTS products (for example ERP system) cannot be changed by users because of absence of source code and other reasons, the integration of COTTS products is usually performed by glueware. Glueware is integration software; it provides the proper interface for a component being integrated and serves as a mediator for its interactions with other components. This proves and supports that improvement actions are required after the ERP system is put into operation by adding some useful features.

III. Research Approach

Research paradigms point to the appropriate methods of inquiry and also direct the researchers to how to conduct the research properly and guide them to success, and the way of knowledge is gained. Therefore, an appropriate research methodology is essential for a research study.

Action research, by definition, means research through action, and usually involves research being part of a learning process and the solving of a problem. According to Burton et al. (2004), action research can be applied to spectrum of issues and setting, including systems improvement, change management, innovation, specific problem solving on theory generation. It attempts to create a more direct link between theory and practical action, to improve the context, understanding and application of practice, and to involve practioners in developing definitions of problems and in implementing change.

Therefore, action learning fits the theme of this research, and the course of actions in this study focuses on improving the user-friendliness of the ERP system by making it easier to use. The type of this action research adopted is 'classical action research". Ballantyne (2004) state that the basis of his action research is "knowledge renewal". This is achieved through an iterative process of action and learning. A classical action research cycle involves change and learning, organized into iterative phases of action and reflection. Reflection leads to understanding, and understanding shared by participants is fed back into action. It is often expressed as a four-step cycle, involving: (1) planning; (2) implementing (action); (3) observing (evaluating); and (4) overall reflection on the results of steps 1-3, as a basis for re-planning.

According to Kemmis et al. (1988), the process of action research consists of defining the initial concept, designing the research strategy based on the goals and objectives arising from the research objectives, planning and implementing the defined action, and then monitoring and evaluating the results, learnings and effects of this implementation. As shown in **Error! Reference source not found.**, upon revision of the plan, after reflection and evaluation, the cycle of plan, act, observe and reflect is repeated.

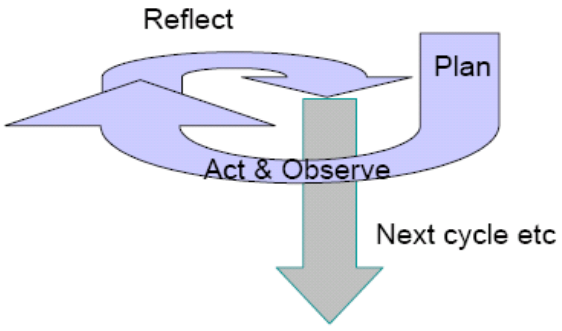

FIGURE I
ACTION LEANING CYCLE (KEMMIS AND MCTAGGART, 1988)

Use of the action research methodology sometimes needs multiple cycles. More generally, in terms of qualitative research, multiple case studies (cycles) are

chosen because according to (Stake, 1995), understanding them will lead to better understanding, perhaps better theorizing, about a still larger collection of cases, and information from various cycles. In addition, the evidence from multiple cases (and cycles) is often considered more compelling, and the overall study is therefore regarded as more robust (Yin, 2009). Therefore, successive action research cycles convert towards a better understanding of practice in action and each successive cycle of action research moves closer to achievement of the research objective. In this paper, various actions have been taken and these actions can be distinct into two major cycles, based upon information collected from 2006 to 2010. According to Marshall et al. (2006), each case included in this research study matched the defined unit of analysis which is a "group of diverse project stakeholders, predefined" valid sample comprised of "people, behaviors, events or process".

One of the prominent criteria for a research design is validity (Yin, 2009, Bryman, 2004, Muijs, 2004, Burton and Steane, 2004). Validity concerns the collected data that can help to measure the matters of the intended study (Muijs, 2004). (Burton and Steane, 2004) agrue the need to decide on the best way to measure in a research. Justifying the validity of the measures, the major issue can be broadly summarized as the measures in an appropriate way to measure whatever the variables are in the study. Therefore, collected data must be logically and accurately consistent and cover comprehensively the aspects related to the study.

According to Muijs (2004), there are three types of validity: content validity, criterion validity and construct validity. Content validity is whether the data collecting tool is right to measure/review the matters that the research is trying to measure/review, and criterion validity refers to the theories that are used in the study are relevant (Muijs, 2004). Criterion validity is self-explantory in the literatures review. Construct validity is about correct operational measures for the concepts being studied and multiple sources of evidence is required (Yin, 2009).

Given the problematic issues associated in case study research from the users, clearly there is an important role for theory in determining content validity and construct validity. The better the subject is known and how the concepts are theoretically defined, the better the design of the instrument is content-valid and construct-valid. The main judgement of whether an instrument is content-valid is therefore its accordance to a theory of how the concept works and what it is. The sources of data collection will improve the research is construct-valid. As this research is trying to review the performance of the ERP system, it is not appropriate to just ask the IT personnel and system maintenance staff within the organization, but should directly collect the views from various users from different projects and departments. Their attitudes and response to the system are most valid. In addition, comments from mangerial personnel and system audit staff have been collected to support the validity.

High-sounding words cannot solve practical problems. One of the major elements of the ERP system is to assist management in making business decisions. After a series of informal interviews with various ERP users in the studied organization in 2003, the author noted that there were some implementation problems of their ERP system. Before taking actions, exploratory surveys had been undertaken in 2006 to diagnosis the underlying problems of using such system. It was followed by a descriptive study in 2007 which concluded that the ERP system is under-utilized and new addictives should be introduced to the existing ERP system.

The following Figure 2 provides an overview of the action research cycles conducted by this research study that is described in this paper, and the next section is going to report such actions learning.

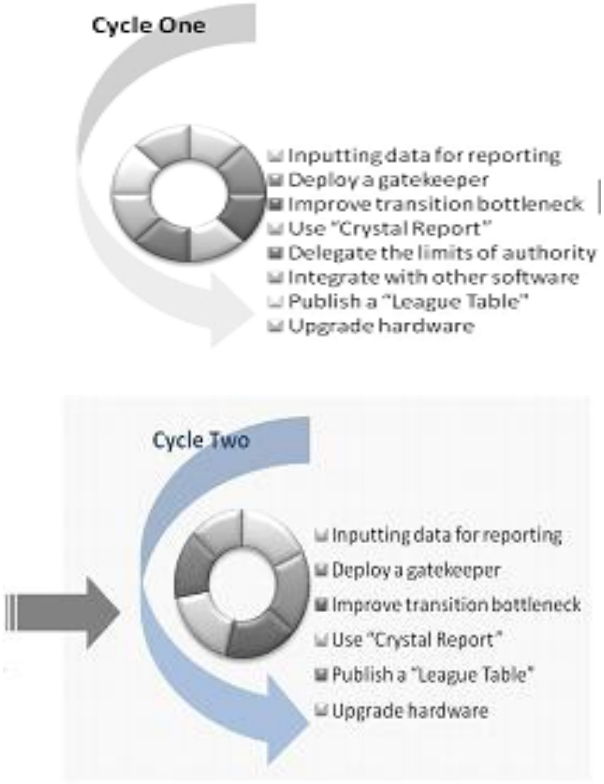

FIGURE II
ACTION LEANING CYCLE (KEMMIS AND MCTAGGART, 1988)

IV. DISCUSSION OF IMPROVEMENT ACTIONS

A better future will only be attained if people strive for improvement. Therefore, improvement actions for a system do require before making that system functioned effectively and efficiently.

A. Background Information

In December 2002, the studied organization (G-Force) started using an ERP platform for its ICT

infrastructure, in order to enhance its information management. G-Force is a construction organization in Hong Kong and expertise in piling, foundations, substructures, tunneling, bridges, building, marine works and water storage schemes. The organization's headquarters is in Hong Kong and it operates throughout Mainland China and Southeast Asia. This organization steadily maintains approximately 11% of the market share out of the whole industry.

The objective of the ERP system was one of "bridging" and "bonding" parts of G-Force's information and knowledge system. This organization intends to use ERP in its construction engineering and project management farmework. The ERP system is expected to link people, projects and various departments together by creating a better internal communication link. Through the use of this ERP system, different parts of G-Force aimed to use configurable information systems packages that integrate information and information-based process within and across-functional areas.

Top management expected the ERP system can streamline and standardize procedures, reduce duplicate administration costs and facilitate a better reporting system. It is hoped that it will facilitate improved decision making through better information flows and improved reliability of cost reporting. However, the perceived benefit of ERP system was not fully obtained after its operation. Staff complained effort was wasted and time was consumed in inputting data. Different staff also used their own methods to input data making standardization was not materially realized. There are also so many overlapping in reports which spent staff's time to align and compare different reporting and format.

After extensive surveys and descriptive study, the following Table 1 summarizes the identified problem areas of the ERP system and corresponding actions were proposed:

TABLE I
SUMMARY OF PROBLEM AREAS AND REQUIRED ACTIONS

Problem Areas	Required Actions
1. Difficult to input correct data	A. Empower frontline staff: delegation of authority
2. Not user-friendly, no tailor-made input screen	B. Improve work flow procedure: multi inputting method
3. Complicated input procedure	C. Ensure smooth process: deploying ERP gatekeeper
4. Complicated cost code system	D. Integrate with different system: 3D modeling
5. Difficult to manage a lot of data	E. Streamline and improve reports: crystal report function
6. Complicated cost allocation system	F. Adjust cost coding: relieve of transition
7. Improve system user-friendliness	G. Involve top management: league table
8. Too many security levels	H. Upgrade hardware: ongoing task
9. Time consuming data input procedures	
10. Unfamiliar reports	
11. Non-interactive help context	
12. Unnecessary multi-handling process	
13. Lack of printing flexibility	
14. Poor hardwares	
15. Unclear feasibility of software upgrade	
16. Affordability of ERP system	
17. Demanding by top management	

B. Intervention Actions

Positive intervened actions are required to improve the ERP tool before making the system being much efficient. Data was then collected, mainly by observations and interviews conducted, between 2006 and 2010, which recorded that G-Force has introduced the following enhancement features within the ERP system:

1) Inputting Data for Reporting

According to Al-Mashari et al. (2003), an ERP system can facilitate IT coordination in control aspects of management and other operational facets. Therefore, it is a link between management and project operation. However, Liaquant et al. (2002) state that an ERP system can be rendered ineffective by being too "time-consuming" or by having excessive "features and complexity". The top management in G-Force would prefer on-line reports to know the financial status of every project, however, in many cases the inputting of a simple item of data requires staff to follow complex procedures which are difficult to learn and memorize. For example data needs to be input by staff from a range of different departments, including quantity surveyor (QS), site clerk, finance department, concrete plant, and HR department. Sometimes, however, staff are not allowed to input different kinds of data of the same category onto the same screen. A good deal of working time is therefore wasted in data inputting. Besides, inputting the same information to create an adjustment line is also time-consuming. According to Vilpola (2008) user-centred design can be applied to ensure the usability of an ERP system. Therefore, more user-friendliness is required for the system so that inputting data is no longer a burden.

The initial ERP system requires the staff to input the data for the monthly "Work Done by Resource" which is the lowest level of detail of the bills of quantities (BQ) and includes thousands of lines of data. One of the inputting staff said that there are 10,000 BQ items

which break down to 70,000 resource lines. This inputting method often spends staff many hours inputting data line by line.

During 2006, in order to reduce the time spent inputting data, the features of "Input Work Done Group" and "Input Work Done by BQ item" were introduced. "Work Done Group" is a group of BQ items that are likely to have the same cumulative work done as a percentage of work done in the interim valuation process. The Work done group number shall be created first and assigned to different BQ group working trades such as preliminaries and structures. When staff assign the cumulative work done by a percentage of a group of BQ items, the system will immediately apply it to the BQ items within the group, which saves a lot of data inputting time.

In 2010, data inputting can be done by using simple spreedsheet, eg. MS Excel. Data is input and imported to the system. This process not only simplifies the input method "by grouping and input a sum of related cost centre" to the ERP system, but also minimize the input by individual resource lines.

2) Deploying the Gatekeeper to Monitor ERP System Working Consistently

Brehm et al. (2001) state that the ERP system is much more complex than traditional software system; requiring users have more knowledge, effort and skill to adapt them to the characteristics of a particular organization. According to Liaquant et al. (2002), the advantages of an ERP system include "avoiding data and operations redundancy". However, it is crucial to keep close monitoring and continuous improvement of production input, processes and output. A position to perform the gate-keeping and monitoring function was therefore required.

Since there are different training programs for users tutored by different trainers, each trainer had different perceptions of "best practice", and the consequence is that different practices and methods are adopted by the users. Moreover, there are some practical problems amongst different users. Submission will then go from doer via gatekeeper to final approver (i.e. Senior Managers or Directors). The duty of the gatekeeper is to maintain standards and monitor the consistent operation of the ERP.

This feature also eliminates the time for re-doing of a submission process should there be any missing information as requested by the final approver (as the gatekeeper has already checked and satisfied that the essential information is attached in any submission for approval). The gatekeeper role also helps to reflect collective views and difficulties from users to top management on whether the ERP system should be modified to suit operational needs.

However, there was only one gatekeeper and he became too busy everyday to check and endorse all ERP's approval within the system. Another competent gatekeeper will therefore be required and must be trained up to help such important task.

3) Improving Transition (from Tender Stage to Project Stage) Bottleneck

According to Brehm et al. (2001), an ERP system can enable adopters to integrate data and processes throughout the organization, and the system support nearly all functional departments, including accounting, human resources, operations etc. However, Liaquant et al. (2002) state that ERP systems require continuous review and development which are very time-consuming. Therefore, any bottlenecks in the flow of information must be eliminated.

The cost code in the system is used to organize the cost code structure to accommodate different people, reporting purposes, and business needs. The purpose of the tendering cost codes is simply to serve the tendering process and they are not structured for reporting purposes. However, the cost code structure for the project costing system resides within the organizational general accounting system and is commonly referred to as the chart of accounts or accounts in the general accounting system. The ERP system therefore links the project cost with the general accounting systems. Both systems share common database tables related to account information, and the account structure and account levels of detail for a project are directly related in each system.

Owing to the different coding systems, some time was spent to verify the codes during the transition (from tender to project), thus delaying project running. Some projects required over a month to complete the transition, which not only affected payments to suppliers and subcontractors, but also delayed monthly reports. A standard template is then developed that mapped the tendering cost codes to the simplified ERP system cost code structure.

This revised features, starting from 2007, aimed at completing of the whole transit process within 4 weeks to enable project reporting. After few years, the transit process have been much improved and simplified. However, some project staff believed that some advanced technique, should be considered and introduced, for example by using MS Excel spreadsheet, simliar to those adopted in inputting data for reporting, may be useful for helping the transit process. For example, in one of their project in 2009, the total number of data lines is over 16,000 rows. The most important work for transition is to verify data (both amount and cost code) before uploading for tranistion. So, how to handle a huge number of resource lines and manage those data efficient is critical. If spreedsheet can be designed and allow them to text it by "trial and error", it will certainly help project inputting staff to verify those data efficiently.

4) Using "Crystal Report" Function

According to Walker et al. (2004), the ideal ICT software should include compatible software applications to allow data and information to pass

seamlessly across and to minimize multiple data entry. The concept of crystallizing the reporting function allows the data entered into the ERP system to be readily transferred to other systems.

Although the ERP system can already produce many different kinds of reports, staff are still required to prepare many supplementary reports manually to suit the specific financial situation of individual projects and preparing some of those supplementary reports are extremely time-consuming. Therefore, Crystal Reports has been introduced into the ERP System as a supplementary reporting tool.

Crystal Reports is in a high standard for desktop and web reporting. It easily creates simple reports and also has comprehensive tools to produce complex or specialized reports. Reports can be published in formats such as Adobe Acrobat (PDF), Excel and Word. This reporting function may be extended to a web-based platform for reporting, analysis and information delivery, which allows staff to view the report through a web browser. That is, everybody who can access G-Force's intranet can view Crystal Reports anywhere and at any time.

The "Crystal Report" function was first introduced in 2005. As this features was so sucessful, further reports could be produced as of December 2010. For example, "Work Completion Report" showing the cumulated concrete ordered and delivered to site can help project staff using it to prepare and update concrete reconciliation report and review wastage control parameter. Using the "Staff & Labour Allocation" which shows the staff / labour allocation for the current month, project staff can use the cost data to monitor the cost overrun versus the budget allowance easily. Furthermore, such data is a good evidence to substiantate contractual claims, if necessary.

5) Revising the "Delegation and Limits of Authority"

According to Fui-Hoon Nah et al. (2003), top management support and ERP teamwork and composition is two of the most critical factors for successful ERP implementation, and these authors also suggest that strong and committed leadership may be able to compensate for the absence of other key social enablers. Such commitment is based upon allocation of all necessary resources, empowered decision-makers delegated authority.

An organization's most valuable resource is its people. It is impractical for any supervisor to handle all of the work of the department directly. In order to meet the organization's goals, focus on objectives, and ensure that all work is accomplished, supervisors must delegate authority. By empowering employees who perform delegated jobs with the authority to manage those jobs, supervisors free themselves to manage more effectively.

One of the problems of the ERP system is the security gateway, and the delegation and limits of authority largely dictate the parameters of the security gateway. In order to speed up the communication flow, consensus from the top management was obtained to revise the delegation and limits of authority to deal with low-level, high-frequency, and day-to-day transactions. For example, miscellaneous off-site purchase orders can be approved by project staff. However, higher-value orders must still be approved by fellow Directors and above in the ERP system at the same time.

6) Integrating the Three Dimensional (3D) Modeling

A COTSS which serves as the backbone of the IT architecture can be integrateded with another disparate software system by a glueware, and then the whole system can be built up effectively (McKinney, 1999, Yakimovich et al., 1999). This improvement action aimed at integrating the 3D modeling in ERP which is also supported by the (CIRC 2001)'s report.

G-Force is the leader in using a 3D modeling design tool in the Hong Kong building construction industry. In one of its pilot projects, all the consultants used 3D modeling software for their design work to achieve well-coordinated drawings that eliminated all clashes. For example, the E&M team used the 3D model to facilitate the coordination of different work, as well as to prepare combined services drawings, combined builder's work drawings, specialist sub-contractors' shop drawings, fabrication drawings, etc. The key advantages of this model are in the areas of design coordination, identifying clashes prior to construction in order to minimize unnecessary work and waste, improving site management and reducing paperwork. The software also allows the design team to "construct the building many times" on the computer. All sorts of scenarios can be previewed and potential problems identified in advance in this simulation process, which performs such tasks as the production, transportation, handling and assembly of different construction components, including all the associated operational processes. All the variables affecting the construction processes, such as site layout, plant locations, rate of machinery operation, quantities of resources, etc., can be considered in order to evaluate the feasibility of the proposed construction methods and sequences, and explore possible solutions and improvements to the methodology prior to actual work beginning.

The 3D model can also be used to monitor actual progress. By linking the master program to the 3D model, the planned construction sequence can be viewed easily. As the project progresses, the actual percentage of progress can be updated at regular intervals. If the project is on time, nothing will be highlighted, but if certain activities are ahead of or behind the planned schedule, they can be easily spotted. This can improve site communication, while helping to visualize and monitor work progress.

7) Publishing the "League Table"

In the ERP system, the information flow and approval are done electronically, but delays in data and information flow are still experienced. One of the

crucial reasons for this is the prolonged time spent by different approvers in the process. In order to encourage all of the users to improve the flow and approval process, an "Approvals League Table" was established. From the business perspective, it is also needed, because G-Force is obliged to pay creditors within a specified timeframe, based upon the subcontract and purchase agreement. This league table was to help the ERP system to excel, because league tables include procurement approval, subcontract approval, payment approval etc. and are maintained daily by IT staff checking the approval process in the ERP system. These tables represent key performance indicators which help the organization to streamline its work processes, and are updated, analyzed and posted on the intranet monthly.

For example, in October 2006, there were 1,438 approvals, 93% of which were approved within 3 days; and 51% on the same day. Previously, the average approval time had been 7-9 days. However, it is questionable that this feature can deliver perceived expectations, because some approvers in order to satisfy the required timeline, they just simply reject/disapprove the submission for approval at the very last minute and deny that additional information is required. This intervention action can satisfy the "time" need, but create a lot of unnecessary resubmission. "League Table" does not really assist improvement and requires further change or enhancement measures.

In 2010, the league table has ben published for few years, and was commented as a "good feature". However, some project staff believed that there still has rooms to improve. Some comments in the league report is unclear and further clarification is always necessary. Also, it provokes huge workload to project staff to input the cost of individual items, such as hardware, electrical cable and distribution board, to the system. It was suggested that a bar code recording system should be developed and introduced which can eliminate time consumed in cost data inputting process.

8) Upgrading hardware

Zhang et al. (2005) suggest that the hardware must be selected according to the specific ERP systems' requirements. According to Walker et al. (2004), performance characteristics of functioning hardware can be viewed from the perspective of: availability (having access to hardware when needed); its currency (the hardware's version relative to that which is currently available); its functionality (the way in which it does what it is supposed to do); and its reliability (working in the way that it is supposed to). Therefore, it is an ongoing exercise for an organization to upgrade the hardware to meet the functional need. G-Force had gradually replaced all old PC for the staff and used LCD monitor instead of TFT one since 2007, and most of the PC was equipped with better software.

C. Outcomes of Intervention Actions

After taking such actions to improve the ERP system, the following Table 2 summarizes and indicates what the intervention addressed and the outcome was.

TABLE II
SUMMARY OF INTERVENTION ACTIONS AND OUTCOMES

Intervention Actions	Outcomes
Improved method of inputting data for reporting	Successfully save the time consumed in inputting data
Deployed a gatekeeper ensure works' consistence	Successfully eliminate resubmission as works are much consistent
Improved transition (tender to project) bottleneck	Successfully relieve the transition bottleneck
Used "Crystal Report" to improve reporting	Successfully produce better reports
Delegated limits of authority to subordinates	Efficiently empower good staff
Integrated with the 3D Modeling	Successfully integrate ERP with other system
Published a "League Table" to show time spent on ERP system process	Only speed up approval and satisfy the "time" need, but create much unnecessary resubmission
Upgrade hardware	Ongoing task

As far as final results of the actions taken are concerned, it is well beyond the time limit available for completing the research study. However, the first significant positive outcome was recorded. In February 2008, G-Force had allied with another contractor (G-Force is the head of the joint venture leading the tendering process) and won a US$500 million design and build project for the government headquarters. That tendering process called for the online Project Data Base System (PDMS) which was intended to be integrated with the client's electronic filing system. The organization's use of IT and ICT system to manage its projects was definitely an advantage (better than the competitors) in this regard, because one of the features of the improved ERP system has similar characteristics and is compatible to the PDMS.

Also, the improved ERP system has also been launched in their Singapore business since 2008.

V. CONTRIBUTION & FURTHER WORKS

The experience and success of the studied organization can perform as exemplar which can be borrowed by those construction engineering companies and project management organization. This action research has developed a management roadmap, as Figure 3, to assist other companies when planning to adopt IT strategy and use ICT tool in their business. It cannot just only simply operate based upon its origin, but also requires the on-going observation and adding improvement features to such tool before the desirable outcome can be achieved.

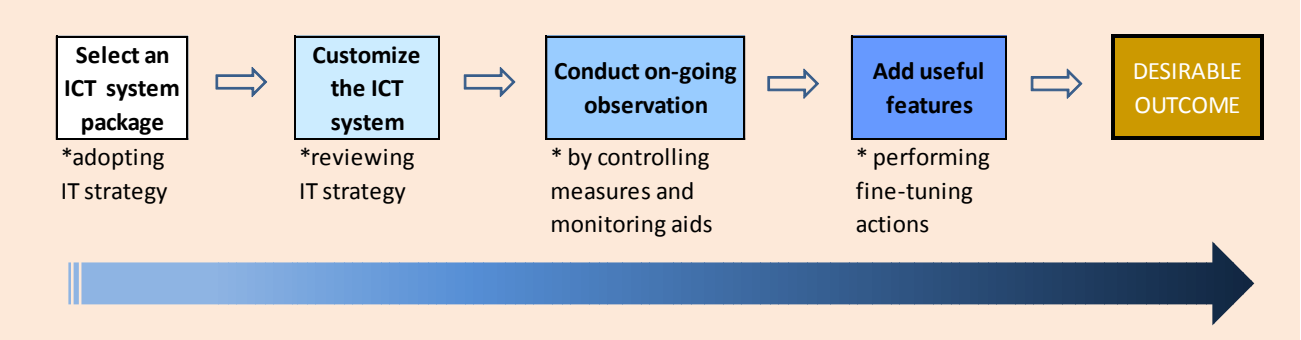

FIGURE III
MANAGEMENT ROADMAP FOR ADOPTING IT STRATEGY AND USING ICT TOOL

This paper suggests that, at the first stage, when organization adopts IT strategy and select an ICT system package, just purchasing a COTSS is not adequate. The second stage is to review the IT strategy by customizing the selected ICT system and modify it in various ways to meet the business needs. The third stage encompasses controlling measures and monitoring aids to the implemented system. This study addresses the issues of identifying variables from theories of improvement and intervention requirement that hinder the effectiveness of ICT implementation. In order to identify what actions may affect ICT performance, the challenge is then to decide how these actions can be implemented in an effective way. These can be done via on-going observation to the system, experiences from users, and comments from managers and system audit staff. These responses help to modify and re-configure the ICT system to suit the business needs. Then, management has to decide what actions can improve the ICT performance. To test such improvement actions influencing the performance at the actual implementation phase, it will place the main focus on performing fine-tuning actions by additional useful features to the ICT system.

The major contribution of this paper is in managerial implications. This study has discovered some different findings to those reported in previous studies because this research emphasises on actual implementation phase. This research find similar factors, such as top management commitment, teamwork, hardware compatibility, integration issues etc. influencing ICT performance (Fui-Hoon Nah et al., 2003, Yakimovich et al., 1999, Somers and Nelson, 2001, Brehm et al., 2001, Walker et al., 2004, Liaquant et al., 2002). However, this study's findings illustrated the dynamic of these factors, by action learning approach, during the implementation phase. The dynamic of these factors', interacted at the actual implementation, reflects the challenges facing by users throughout various departments and different projects within organisations when adopting ICT. Therefore, this study has contributed to a more holistic appreciation of what is happening from strategic phase as well as during actual implementation. This will be very useful for management in making IT/ICT investment decision.

There are at least two limitations pertaining to this study. Firstly, this research is limited to one type of ICT tool, i.e. the ERP system. Therefore, it will be interesting to study the performance of other ICT tools such as "Project Management Planner", "Building Information Model", "Project Database System", "Enterprise Wide Information Systems" etc. A future study of this kind can help to justify the reliability of the proposed management roadmap in Figure 3. Secondly, due to the research was undertaken within a limited timeframe, those observed actions were only recorded between February 2006 and December 2010, and two cycles have been taken place. The whole cycle for action learning includes planning, actioning, evaluating and concluding overall reflection on the results, as a basis for re-planning (Ballantyne, 2004). It will be desirable if there is a further improvement and intervention actions cycle so as to validate and consolidate the performance of the ERP system resulted from the previous action cycles.

VI. CONCLUSION

The purpose of this paper is to review and report the action research, through the experience of a construction company G-Force, of using of ERP system in construction engineering and project management. In summary, after extensive literatures review and the design of the research approach, this paper records those implemented actions and the observed interventions, in two cycles, which have been taken place by from 2006 to 2010. Those actions include improving data inputting method; removing the transition bottleneck; introducing crystallization function; revising the organization's "Delegation and Limits of Authority"; publishing the "League Table" amongst users; integrating the 3D Modeling into the system and upgrading hardware.

This research reveals that IT has been widely accepted as an important business strategy and many construction companies and project management business has used ICT tool to assist its management. However, some organizations fail to adopt the proper IT strategy and effectively utilize the ICT system to meet the changing business needs. Sometimes, organization just purchases a COTTS and operated in its origin.

Although some may customize the system, it still cannot achieve a satisfactory result. Many IT strategies have been planning thoroughly and neatly at the early stage. Careful selection of the system, detail preparation for transition and training programme do not guarantee a success, but they fail once implemented. One of the major impacts on the success is the requirement of adequate follow up actions. The whole IT strategy and use of ICT are not only limited to theory and initial works but extend to other practical management issues after they are launched and implemented. The studied case of G-Force illustrates that long-term observations and fine-tuning actions to the system are required before the perceived goals and desirable outcomes are achieved. Whilst such actions may not be standard that can be imitated by other organizations, the lesson learnt can be borrowed in planning the IT strategy and using ICT system before investment decision and actual implementation. This action learning leads to a management roadmap, as Figure 3, which can assist those construction engineering and project management companies to plan for their own IT and ICT strategies.

Direct success of those improvement actions is difficult to measure. However, it is recorded that the studied organization G-Force allied with another contractor and won a US$500 million landmark project. G-Force successfully implements its IT strategy and use the improved ICT system to manage the projects is definitely an unqiue competitive advantage leading to such award. As a good model, that improved ERP system has also been successfully launched in their regional business at Singapore.

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