Impacts of Adding Knowledge Flow to an Activity-Based Framework for Conceptual Design Phase on Performance of Building Projects

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Abstract: The construction industry suffers from an incomplete knowledge flow that leads to overrun cost and time. A considerable portion of this problem is attributable to the design stage which is a tacit knowledge-dominated area. Since knowledge tacitness results in an incomplete knowledge flow, we posit that adding the knowledge flows beside the workflow of the architectural conceptual design phase can attenuate both the overrunning cost and time. In order to fulfill such an objective, we integrated the Nissen multidimensional model – the knowledge flow theory for the enterprise life cycle – with Macmillan's framework – the conceptual design framework – to test whether or not adding the knowledge flow to the conceptual design work flow could attenuate the cost and time overrunning. This paper elaborates on the process of validation testing by means of Simvision. Analysis of the results reveals that specifying the entity of the required knowledge during the conceptual design phase could reduce the cost and time overruns.

Keywords: Knowledge flow, tacit knowledge, knowledge transfer, work flow

1. Introduction

This paper comprehensively deals with the procedure of validating the extended knowledge-based framework (proposed by Pourzolfaghar et al., 2011) for the conceptual design phase of the building projects. Such a framework lends its basis to Macmillan's (2001) conceptual design framework which entails a workflow for the conceptual design. In details, Pourzolfaghar et al. (2011) attempted to extend the activity-based framework of Macmillan's by adding the required mechanical/electrical knowledge for the conceptual design phase. According to Nissen and Levitt (2004), knowledge flows enable the workflows and this is why they are indispensible for the organizational performance. Nissen (2006) also emphasizes that accompanying the required knowledge with the workflow can improve the performance. In this study, we attempted to prove through intellective validation by utilizing Simvision that the extended knowledge-based model would improve the performance of the project.

2. The Background Problem and Literature Review

It has been confirmed by numerous researchers such as Paulson (1976), Jin & Levitt (1996), Martinez (1998), Ibrahim (2005), Ibrahim & Paulson (2008), Ahmed (2005), Nissen (2006), and Ibrahim & Nissen (2007) that there is a problem with the knowledge transfer in the construction industry which leads to cost and time overruns in the building projects. In addition, some other researchers including Cronik (1991), Rounce (1998), Macmillan (2001), Pektas & Pultar (2005) have accentuated that the design which gives rise to the wasted time and cost would form a largest category. Simultaneously, Ibrahim and Fay (2006) contend that the design process is a tacit dominant stage while there is unfortunately scarcity regarding the literature on transferring the tacit knowledge as stated by Alavi and Leidner (2001). With support from Ibrahim & Paulson (2008) stating that the knowledge type contributes to the knowledge loss phenomenon, this study posits whether it is possible to mitigate the time and cost overruns if the transfer of the tacit knowledge is facilitated.

Nissen (2006) further explains in his multidimensional model for the product life cycle that the knowledge which is transferred to the other experts through sharing the experience is of a tacit type. According to his model, the tacit knowledge originates from a heavy mass while contributing to the long flow time. Henceforth, the knowledge transfer maybe improved through this phase by finding a way to convert the required tacit knowledge for the conceptual design stage to the explicit type. It is distinguished that numerous professionals from various fields such as mechanical, electrical, and structural professions are involved during the conceptual design stage. To date, several researchers have recognized mechanical and electrical considerations as the most problematic areas during the conceptual design phase.

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According to some researchers such as Rounce (1998), a considerable amount of the wasted time is attributed to the design stage. Bearing in mind that the design stage is a tacit-dominated area and also considering the difficulty of organizing the tacit knowledge, Pourzolfaghar et al. (2014) proved that the knowledge capture can be improved when the design professionals know what the required knowledge is and when it is required during the conceptual design phase. Like so, the scholars endeavored to extend Macmillan's (2001) activity-based framework into a knowledge-based framework with the aim of developing a tacit knowledge capture technique for the architectural conceptual design phase. In his multidimensional model, Nissen (2006) attempted to examine the knowledge movement among the experts through a project life cycle in terms of knowledge typology. Pourzolfaghar et al. (2011) tried to utilize the Nissen's theory for detecting the knowledge movement between the experts during the conceptual design phase. According to Nissen, the knowledge that moves from an individual to a group is of the tacit type which afterward moves to the explicit level through the formalization step. In practice, Pourzolfaghar attempted to explicate the knowledge when it moves from an individual to a group. As such, the first two steps involved in the knowledge life cycle which lend their bases to the Nissen's theory are simultaneously performed, contributing to a decline in the required time. It should be pinpointed that Pourzolfaghar et al's knowledge-based framework (2011) entails the entity of the required mechanical/electrical knowledge (Table 1 and 2).

Table 1. The Knowledge-Based Framework for the Conceptual Design Phase, activities 1-6 (Source from Pourzolfaghar et al., 2011)

#	Macmillan Framework Activities	Knowledge From			
		Architect side		Mechanical side	
		Entity of Knowledge	Data	Entity of Knowledge	Data
1	Specify the business need	Specify kind of building (function)		Specify required technologies: BIPV requirements	
		Site characteristics		Solar air conditioning requirements	
		Owner aspirations		Wind turbine requirements	
		Exist building problems		Rainwater harvesting system requirements	
		Mission statement about requirements		Waste management requirements	
				Daylighting requirements	
2	Assessing stakeholders requirements	Building modules regarding defined mission		BIPV location, tilt angle and direction	
				Rainwater usage, location and storage tank requirements	
				Daylight strategy to catch optimum sky light	
				Solar air conditioning area needs	
				Wind turbine location and requirements	
3	Identify problems with exist solutions			Sun path movement	
				Wind direction	
				Constraints arising from technologies such as wind velocity points	
4	Developing requirements	Space function and requirements		Minimum daylight standard for spaces	
		Standard modules		Ventilation requirements (such as required space between blocks)	
		Height of buildings		Pressure variants	
				Necessity of mechanical ventilation due to stack effect (caused by height of building)	
5	Setting requirements	Specify drawing requirement and diagrams		Solar collector location	
				Water catchment location	
				PV panels location, tilt angle and location	
				Wind turbine location	
6	Determining project characteristics				

Table 2 Knowledge-Based Framework for Conceptual Design Phase, activities 7-12 (Source from Pourzolfaghar et al., 2011)

#	Macmillan Step	Knowledge From: Architect side – Entity of Knowledge	Architect side – Data	Mechanical side – Entity of Knowledge	Mechanical side – Data
7	Generating initial concepts			Specify effect of courtyard for	
				Better distribution of daylight	
				Use of building shade	
				Specify PV panel location base on need to cool	
8	Transformation / Combination of concepts	Design alternatives for building modules			
		Specify width and length of buildings			
9	Selecting suitable combinations	Specify size of blocks of buildings			
		Specify space between buildings			
10	Firming up into concept proposals	Alternative forms of design		Finalize PV location	
		Specify height of buildings			
11	Evaluating and choosing proposal	Specify chosen alternative		Rainwater catchment diagram	
12	Improving detail and costing proposal			Estimating storage tank base on roof area	
				Specify location of pump and water tank	
				Estimation of needed air condition	
				Cooling capacity	
				Estimation of needed space needed for solar requirements	
				Life cycle cost	
				Estimation operating cost saving	

It needs to be asserted that using this framework results in saving the time for performing the “Identify Knowledge” activities -which were implicit with the conceptual design activities. Like so, this study expects shortening the work duration associated with the project. As stated by Pourzolfaghar et al. (2011), employing this framework during the conceptual design phase of the building projects may facilitate capturing and formalizing the experts’ tacit knowledge. This paper is an explanation on the process of validating the developed tacit knowledge capture technique.

3. Research methodology

This study made use of the SimVision software to address the effects of dealing with the tacit and explicit knowledge through the simulation process. Ibrahim and Nissen (2007) had employed this software earlier as an agent-based tool that allowed evaluating the multiple workflows in a single process. In dealing with the tacit knowledge, the project performance relies on the experts’ experience; the higher the skill of the experts, the more complete knowledge is transferred/retrieved, and vice versa. In the tacit dominant area, completeness of the tacit knowledge movement relies on the skill of the experts involved in the process. Therefore, the work duration will be affected by altering the experts’ skill levels. Contrariwise, the entity of the required knowledge is already specified while dealing with the explicit knowledge. Hence, the experts’ skills will not be able to affect the completeness of the required knowledge to be transferred or retrieved. In other words, a given knowledge in the explicit dominant area has to be transferred or retrieved and the activities, which mostly belong to the tacit dominant area, for specifying the entity of the required knowledge are deducted. In order to fulfill such an objective, both Macmillan’s framework and Pourzolfaghar et al’s knowledge-based framework were tested and compared as two cases for the simulation. This study compares the results obtained from the simulation of these two frameworks. In practice, the study compares the work cost, the work duration, the PRI (Project Risk Index), and the FRI (Functional Risk Index) for both models. After simulating Pourzolfaghar's knowledge-based framework (2013), this study uses the FRI and PRI values for the subsequent reasons:

- To compare the FRI and PRI values for the existing framework and the proposed framework of this study and to inspect the effects of adding the required knowledge to Macmillan's framework.
- To ensure that the mentioned values are acceptable (FRI<0.5; PRI<0.5). In other words, the current study attempts to ascertain that adding the required knowledge to the existing work flow does not exert negative effects on the results.

3.1 The Model Simulation

We employed SimVision, the educational version 4.2.0, which was developed by Vite Corporation with a license from ePM. Ibrahim (2005) states that there are three items which are of significance while studying the knowledge flow in any organizations, namely the process under study, the organization, and their connections. Since the flow of knowledge is engaged with the passage of time as the process progresses, SimVision links the process to its organization. For the first time, Nissen and Levitt (2002) attempted to simulate the knowledge flow in the design of the organization by using a computational method (Simvision).In line with this, they used a theory for multidimensional conceptualization of the knowledge-flow phenomenon to develop the dynamic models of the knowledge flow dynamics. They illustrated their research approach and the modeling environment through formal representation and simulation of several knowledge-flow processes by means of SimVision. Moreover, Ibrahim and Nissen (2007) extended the organization theory by integrating it with the knowledge-flow theory, while making use of the computational methods and tools to recognize how discontinuous membership would affect the organizational performance. Likewise, we utilize the computational modeling to inspect the effects of adding knowledge to the workflow of the conceptual design phase since this study is mainly concerned with the knowledge flow during the conceptual design process.

It needs to be reminded that Macmillan's (2001) framework forms the basis of the current study for the conceptual design phase. Using this software, we attempted to create the conceptual design workflow adopting Macmillan's (2001) framework for this stage. Although Macmillan's (2001) conceptual design framework entails12 main activities, there are some implicit activities which function to determine the required knowledge as well as exchanging the required knowledge. Therefore, we added two activities following each activity proposed by Macmillan's framework. In conclusion, the process of the conceptual design entails 36 activities which stem from Macmillan's model along with 24 more additional activities for identifying and exchanging the required knowledge for each activity.

The current study was an effort to implement Macmillan's framework as the base case. As it is exhibited in Figure 1, Macmillan's main activities are presented in lighter colors. Moreover, it is discerned that the activities are ordered in columns. For instance, the first activity is "specifying the business needs". The next activity in the first column is "identifying the required knowledge". The following activity is for "exchanging the required knowledge". Other activities are ordered accordingly. In SimVision, we have to assign the activities to the project team members. Many experts such as the project manager, architect, and the mechanical/electrical engineers are involved in the conceptual design phase; therefore, each activity is assigned to all of these experts. Like this, we can examine the effects of these experts' skills on the project performance.

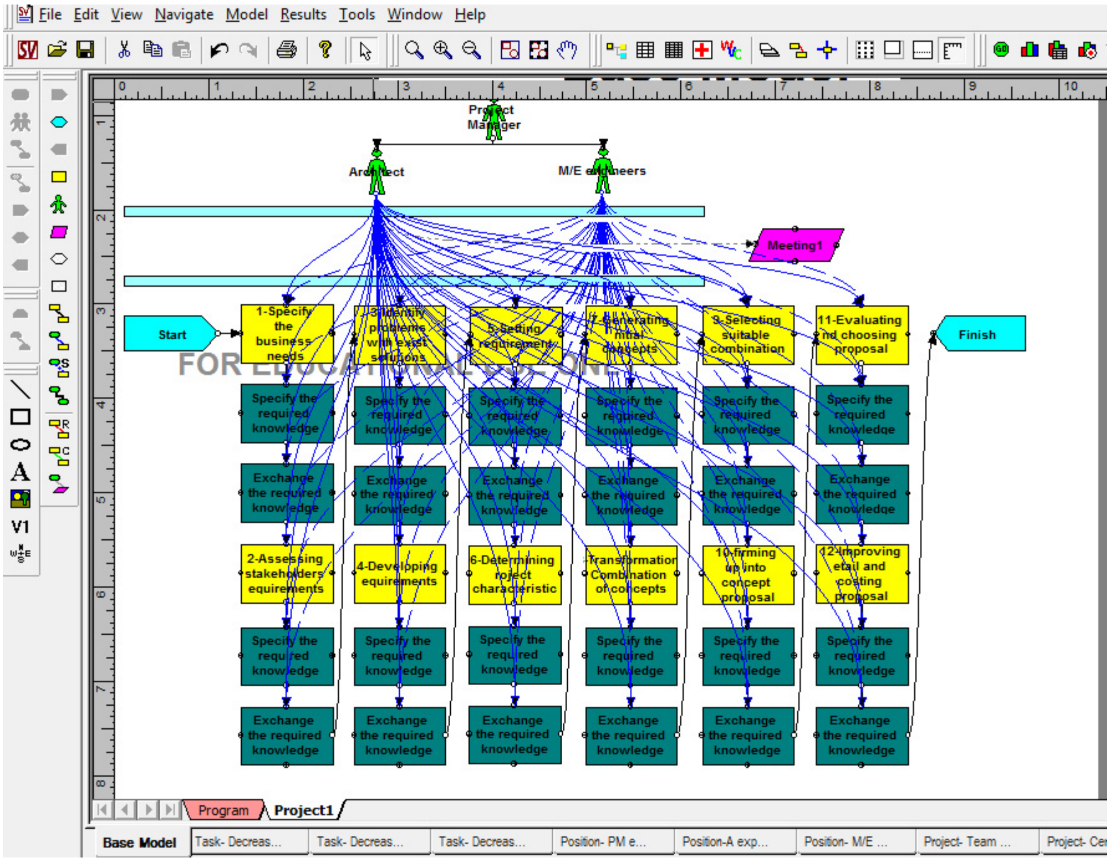

Figure 1. The Base Framework for the Conceptual Design Phase

According to the Nissen's (2006) multidimensional model, the knowledge moves from the individuals to the group through sharing the experience. At this instant, if the experts' skills match the required experience for the related task, the person in charge will know the accurate and complete knowledge which has to be transferred. As a result, completeness and accuracy of the knowledge obtained by the receiver would depend on the senders' skill. In a tacit dominant area such as the conceptual design phase, the performance of the successor's task relies on the received knowledge which has been sent by a provider. Therefore, all the team members' skills can affect the knowledge exchanging process between the experts and the project performance as well. It needs to be highlighted that these experts' skills (experts' tacit knowledge) would exert an undeniable effect on the performance of the project (Table 3). According to this table, the required skills for the team member consist of the Medium level for Project Manager (PM), the High level for the Architect (AR), and the High level for the Mechanical/Electrical engineer (ME). Because these experts possess the required skills, they are able to provide the required knowledge at the right time. If an expert such as an architect does not possess the required skill level, other team member's task will suffer from his/her incomplete knowledge transfer. Having considered all the above mentioned notions, this study establishes the following hypotheses:

> ***H1:*** *A building project team member who has sufficient knowledge required for the other team members' tasks can improve the performance of the receiver's task. The study expects the FRI and PRI to be less than 0.5.*
>
> ***H2:*** *A building project team member who does not have sufficient knowledge to be considered by the other team members to do their task can increase the risk involved in the receiver's task by transferring incomplete knowledge. The study expects the FRI and PRI to be less than 0.5.*

To prove the abovementioned hypotheses, a comparison and contrast on the results would be established when a team member– such as the architect– possesses the required skill which matches the required experience to participate in a project with the situation in which the same person does not have it.

Table 3: The team members' awareness about the required knowledge

Awareness	PM	AR	ME
Sufficient	Medium	High	High
Insufficient	Medium	Medium	High

In such a situation, the project manager's skill (PM) as the leader of the design team has a great impact on the knowledge exchange process. If the project manager knows that some knowledge is required to be exchanged at a certain time, he will facilitate this process, accordingly. Hence, explication of the entity of the knowledge required to be considered during the conceptual design phase can affect the project performance. In other words, when the entity of the required knowledge has been specified, we can avoid spending time on identifying it. In such a situation, the team members deal with the explicit knowledge which does not depend on the skill of the experts involved. For that reason, the current study establishes another hypothesis regarding the Nissen's theory (2006):

> ***H3:*** *By specifying the entity of the required knowledge during the conceptual design phase, performance of the building project improves due to the explicitness of the knowledge entity. The study expects the FRI and PRI to be less than 0.5.*

For instance, when an architect knows the entity of the required mechanical/electrical knowledge which has to be considered through each step of the conceptual design, the time needed to determine the required knowledge will be accordingly reduced.

Test case 1: the Base Case (Sufficient Awareness)

Following Ibrahim and Nissen's (2007) example, this study proposed a situation where in a small number of task volumes in the base case exists, the behavior parameters we reset are higher than the normal in the construction industry to amplify the effects of the knowledge flow on the outcome. According to SimVision, a project represents a work process when it must be performed by the project team members to achieve an outcome. Each project is composed of tasks, positions, milestones, meetings, as well as links between the components. We set the parameters for the project, positions, and tasks as follows: a medium level for the team experience, a low level for centralization, a medium level for formalization, a medium level for the matrix strength, 0.7 for communication probability, and finally 0.15 for the noise problem, project error probabilities as well as for the functional error probability. As mentioned before, the values of the above said parameters were set in accordance with the normal construction industry values. The position parameters for experts (including the project manager, the architect, and the mechanical/electrical engineers)are tabulated in Table 4. The micro-behaviors included the fulltime-equivalent (FTE), the role, the application experience (App. Exp.), and the salary.

Table 4: The Baseline parameters for the team members

#	Position	FTE	Role	Application Experience	salary	Knowledge Skill
1	Project Manager	0.3	PM	Medium	100	Medium
2	Architect	1	SL	High	80	High
3	Mechanical/Electrical Engineer	2	ST	High	70	High

In the base case, all the team members' skills satisfy the required skill for carrying out the job. For instance, the required skill for the architect and the mechanical/electrical engineers is high. In the case base, these experts' skills satisfy the required skill, meaning that the architects and mechanical/electrical experts are fully aware of the knowledge which needs to be exchanged between the experts.

Test case 2: the Proposed Case (Insufficient Awareness)

The second case test is about insufficient awareness of the experts. All the project, positions, and tasks parameters resemble the ones in the case test. To represent the effect of the experts' insufficient awareness on the performance, we changed their skill. Accordingly, the skill of the architect changed from High to Medium in order to gauge the effects of the experts' skill on the project performance (Table 5). As it is shown, the skill of the architect has not fulfilled the application experience requirements, indicating that the architect does not have the sufficient knowledge to accomplish his/her own task.

Table 5. The Changed parameters for the architect skill

#	Position	FTE	Role	Application Experience	Salary	Knowledge Skill
1	Project Manager	0.3	PM	Medium	100	Medium
2	Architect	1	SL	High	80	**Medium**
3	Mechanical/Electrical Engineer	2	ST	High	70	High

4. Results and Analyses

We made 3 simulations for the base case, changing the experts' skills as well as setting the "*Identify Knowledge"* activities' duration to 0. By setting the trials to 50, we ran 150 trials. Different simulations were made because these experts had different roles while the current study needed to examine the effects associated with changing each condition. The first simulation was for the base model in which the experts' skills met the application experience requirements. The next simulation was for changing the architect skill from High to Medium. The last simulation was for setting the duration of the "Identifying Knowledge" activities to 0 which stemmed from explicating the required knowledge. It was finally observed that all the simulations yielded similar results for changing micro-behavior parameters.

In the stated hypotheses, we claimed that changing the experts' skills in the tacit dominant area would affect the project performance. Consequently, we examined the difference between the parameters' values before and after changing the architect's skill levels. As such, we intended to demonstrate the occasion when an experts' skill level can affect some parameters such as rework, coordination, etc. According to the results obtained from changing the architect's experience level from High to Medium rework (12.8 days to 18.23days), there would be a rise in the coordination (22.63 to 30.43) and decision wait (14.70 to 22). Statistics also showed that by changing the architect's skill level from High to low, the duration would increase from 11 days to 13.5 days and the total work cost would rise from 98941 to 120324 (Table 6). The right-side column in Table 4 illustrates the amount of the increase in the percentage resulting from changing the architect's skill. Indeed, Table 4 refers to hypotheses 1 and 2 that are related to the skill level of the team members. A considerable effect related with changing the architect's skill level on the parameters of the project performance was also established after comparing the project parameters with one another.

Table 6: The Effects of changing the architect's skill level on the project performance parameters

Affected Item	Parameters' Value Base on Architect Skill Level		Difference %-Arising from Changing Level of Skill
	High	Medium	
Work Duration	11	13.5	22.7%
Total work cost	98941	120324	21.6%
Rework	12.8	18.23	42.4%
Coordination	22.63	30.43	34.5%
Decision wait	14.70	22	49.6%

It should be admitted that the abovementioned results are related to the first and second hypotheses of this study which pertain to the characteristics of the tacit dominant area. We claimed that changing the skill of the experts involved in the project could affect the performance of the team members while dealing with the tacit knowledge. The diagram of the differences resulting from changing the architect's skill is displayed in Figure 2, revealing that there is a relation between the level of the architect's skill and the project parameters. By changing the skill level from High to Medium, there will be an increase in the values of the parameters i.e. the work duration, the rework, the coordination as well as the decision wait. In other words, the completeness of the sent/received knowledge by the architect depends on his/her skill. The architect's awareness of the knowledge required to be sent or received would considerably decrease the parameters of the project.

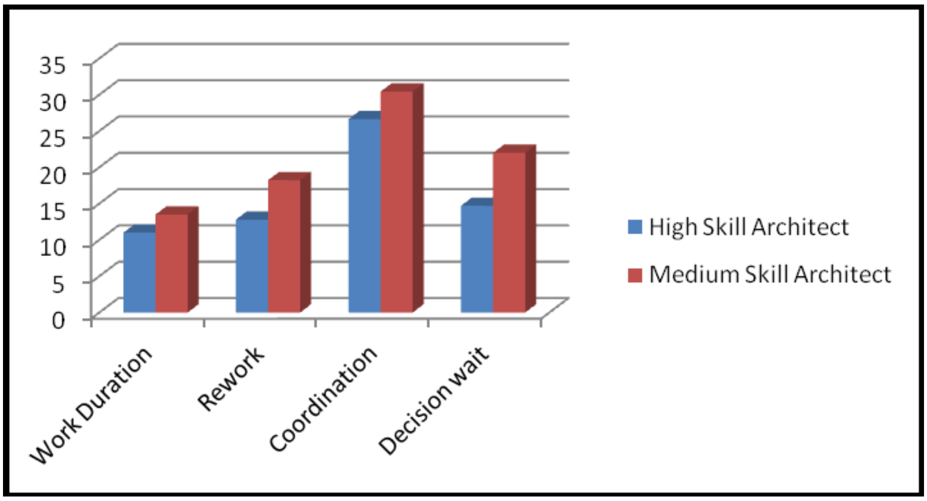

Figure 2: The Parameter Changes Arising from Changing the Architect's Skill

As mentioned earlier, the last simulation was conducted for setting the duration of the "identifying knowledge" activities to 0 which stemmed from explicating the entity of the required knowledge. Indeed, this simulation was related to the third hypothesis. In practice, we made three more simulations in connection with the properties of the explicit dominant area. According to the third hypothesis, adding knowledge to Macmillan's (2001) framework for the conceptual design phase will eliminate the need for identifying the required knowledge. The obtained results from this simulation a represented in Table 7, in which the "Base Case" column contains the simulation values for Macmillan's conceptual design framework. The next right-side column is for changing the "Identify Knowledge" activities to 0. Comparing these two columns reveals that the work duration and the total work cost have considerably decreased. Referring to the results, it becomes apparent that adding the knowledge flow to the work flow in Macmillan's model reduces the work duration (by 33.6%), the total work cost (by 33.3%) and also the FRI (by 3.3%).For instance, the work duration of the base case decreases from 11 days (SD=o.5) to 7.3 days (SD=0.3). Although the functional risk has increased by 3.3%, its value is still under 0.5 (Based on SimVision FRI<0.5 is an acceptable range for this parameter). More discussions on the results will be presented in the next section.

Table 7: The effects of removing the "Identify Knowledge" activities due to adding the knowledge flow to Macmillan's (2001) conceptual design process

Affected Item	Base Case		"0" Duration for "Identify Knowledge" Activities		Difference %
	Value	SD	Value	SD	
Work duration	11 days	o.5	7.3 days	0.3	-33.6%
Total work cost	$98941	0.0	$65967	0.0	-33.3%
Process quality risk	0.28	0.027	0.29	0.033	+3.6%
Product quality risk	0.15	0.014	0.15	0.018	0
Functional risk index	0.30	0.029	0.29	0.036	-3.3%

Indeed, Table 7 contains the values to prove hypothesis 3 whereby we claimed that explicating the required knowledge during the conceptual design phase can improve the project performance. As demonstrated, the work duration and the total work cost have considerably reduced.

5. Discussions

As mentioned earlier, Macmillan's (2001) framework contains 12 explicit and 24 implicit activities. The implicit activities correspond to the explicit ones to identify and exchange the required knowledge required to be considered through the activities. For instance, the sun path movement is one of the basic mechanical requirements which needs to be considered to orient the building. In this respect, a novice architect needs to interact with the mechanical/ electrical engineers to identify the required considerations. Then, he would also need to obtain the identified knowledge at the proper time. In such a situation, explicating the entity of the required knowledge can reduce the required time for the implicit activity for identifying the required knowledge. Moreover, explication of the required knowledge reduces the probability of the incomplete knowledge flow.

To prove this study's claim, we used computational organization tool (SimVision) to simulate Macmillan's (2001) framework as the base model and knowledge-based framework by pourzolfaghar et al. (2011). The results of changing the level of the architect's skill indicate lower organizational performance in terms of the parameters of the project, namely the work duration and the rework. By changing the level of the architect's skill from High to Medium, the work duration increases from 11 days to 13.5 days. This result is equivalent with the rework, where the Medium level skill of the architect has more rework than the High level skill. The estimated rework with a High skill architect is 12 day, while with a Medium level skill it rises to 18 days. The work duration also concurs with the coordination, where the Medium level of the architect needs further coordination than the High level skill for an architect (22 days are needed for coordination in comparison with 30 days). Finally, the work duration concurs with the decision wait, where the Medium level of the architect' skill causes more decision wait than the High level skill (14.5 days is required for the decision wait in comparison with 22 days).

According to the simulation results, after changing the architect' skill level ,the work duration, the total work cost, the rework, as well as coordination and decision wait parameters were all affected in a negative way. Indeed, by decreasing the architect' skill level all the above mentioned parameters increased considerably. The obtained results revealed that there is a negative relationship between these parameters and the experts' skill. In conclusion, this study finds out that the level of the architect's experience during the concept design has a conspicuous effect on the project performance, implying that the time needed to identify and obtain these results from the mechanical/electrical engineers will be saved when an architect has sufficient knowledge about the technology requirements such as the positioning of the building blocks with respect to the existing structures –for example a solar bowl. As a result, the saved time reduces the entire work duration of the project. In brief, these results support hypotheses 1 and 2.

Nissen (2006) has claimed that the explicit knowledge contributes to a shorter flow time. Thus, we attempted to simulate an ideal condition in which the duration of the "Identify Knowledge" activities was set to 0 through adding the knowledge flow to the existing work flow for Macmillan's (2001) model for the conceptual design phase. As mentioned earlier, setting "Identify Knowledge" activities to '0' pointed to the time saving which stemmed from explicating the entity of the knowledge in Pourzolfaghar et al.'s (2011) framework. In conclusion, based on the obtained results, there was a considerable reduction in the work duration and the total work cost for the conceptual design phase. Finally, the results together with the comparison made between similar parameters for the base case and simulated cases revealed that explicating the required professionals' tacit knowledge results in the improvement of the performance of the project.

6. Conclusions

In this study, we attempted to substantiate the knowledge-based framework proposed by Pourzolfaghar et al. (2011) for the conceptual design phase of the building project using Simvision. To do so, we developed three hypotheses arising from the tacitness and explicitness of the knowledge. Then, this study compared the results coming from the simulations of these two frameworks suggesting that in the tacit dominated area the experts' levels of skill affect the performance of the project considerably. Therefore, the conceptual design phase of the building projects as a tacit dominated area is subjected to the skills of the experts involved. In other words, the completeness of the exchanged knowledge is dependent on the experts' skill level. By counting on their experiences, the experienced experts may know the required considerations in different professions whereas the novice team members may not possess the sufficient knowledge on these considerations. The insufficient knowledge of the novice team members may result in the failure in considering the requirements which result in the rework. However, by specifying the entity of the required knowledge, there is no need to identify what knowledge is required through each activity. Therefore, a great deal of time is saved through eliminating the "identify knowledge activities". The results from the simulations are used to corroborate this statement. Like so, this study attempted to inspect the impact of adding the knowledge flow to the conceptual design workflow (Macmillan framework, 2001). To fulfill this, the results of the simulating knowledge-based framework by Pourzolfaghar et al. (2011) and Macmillan's framework for conceptual design phase were compared. Simulations revealed that by adopting the knowledge-based framework (Pourzolfaghar et al., 2011) which embraced the entity of the required mechanical/electrical knowledge during the concept design phase, the cost and duration of the project would certainly decrease. According to the results obtained in the current study, it can be concluded that by employing the knowledge-based framework, the knowledge flow can be improved which accordingly reduces the overrunning of the time and cost.

References

Ahmed, P. K., Lime, K. K., & Zairi, M. (1999). Measurement Practice for Knowledge Management. *Journal of Workspace Learning: Employee Counselling Today, 11* (8), 304-311.

Alavi, M., & Leidner, D. E. (2001). Review: Knowledge Management and Knowledge Management Systems: Conceptual Foundations And Research Issues. *MIS Quarterly, 25* (1), 107-136.

Cornick, T. (1991). *Quality management for building design.* London, UK: Butterworth-Heinemann.

Ibrahim, R. (2005). *Discontinuity in Organizations: Impacts of knowledge flows on organizational performance.* Doctoral Dissertation, Stanford University, Stanford.

Ibrahim, R., & Nissen, M. (2007). Discontinuity in organizations: Developing a knowledge-based organizational performance model for discontinuous membership. *International Journal of Knowledge Management, 3* (1), 18-36.

Ibrahim, R., & Paulson, B. (2008). Discontinuity in organisations: Identifying business environments affecting efficiency of knowledge flows in Product Lifecycle Management. *International Journal of Product Lifecycle Managemnet, 3* (1), 21-36.

Jin, Y., & Levitt, R. (1996). The Virtual Design Team: A Computational model of project organizations. *Computational and Mathematical Organization Theory, 2*, 171-196.

Macmillan, S., Steele, J., Austin, S., Kirby, P., & Spence, R. (2001). Development and verification of a generic framework for conceptual design. *Design Studies, 22*, 169-191.

Martinez, M. N. (1998). The collective power of employee knowledge. *HR Magazine, 43* (2), 88-94.

Nissen, M. E. (2006). Harnessing Knowledge Dynamics: Principled Organizational Knowledge and Learning. Hershey, PA:IRM Press.

Nissen, M.E. & Levitt, R.E. (2002). Dynamic Models of Knowledge – Flow Dynamics, CIFE.working Paper #76 November.

Nissen, M.E. and Levitt, R.E. (2004). Agent-based modeling of knowledge dynamics. KnowledgeManagement Research and Practice, 2(3),169–183.

Paulson, B., & Jr. (1976). Designing to reduce construction cost. *Journal of the Construction Division, 102*, 587-592.

Pektas, S. T., & Pultar, M. (2006). Modelling detailed information flows in building design with the parameter-based design structure matrix. *Design Studies, 27*, 99-122.

Pourzolfaghar, Z, Ibrahim, R, Abdullah, R, Adam, N. M. (2011). Potential technique for capturing building design tacit knowledge to decrease cost and time overruns. In Proceeding of ECRM-The 10th European Conference on Research Methodology for Business and Management Studies, p 605, Academic Publishing, Normandy Business School, Caen, France.

Pourzolfaghar, Z., Ibrahim, R., Abdullah, R., Adam N. M., Abang, A. A. A. (2013). Improving Dynamic Knowledge Movements with a Knowledge-Based Frameworkduring Conceptual Design of a Green Building Project. .*International Journal of Knowledge Management*, 9(2).

Pourzolfaghar, Z., Ibrahim, R., Abdullah, R., Adam, N. M. (2014) 'A Technique to Capture Multi-Disciplinary Tacit Knowledge during the Conceptual Design Phase of a Building Project', *Journal of Information and Knowledge Management* , 13(2).

Rounce, G. (1998). Quality, waste and cost considerations in architectural building design management. *International Journal of Project Management, 16* (2), 123-127.