ACCEPTABILITY OF MALAYSIAN CONSTRUCTION PRACTITIONERS IN ADOPTING 4D

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Abstract

The problem of delay in construction industry is a global phenomenon and the construction industry in Malaysia is no exception. In the current day context, despite significant benefits in terms of time and cost savings gained through the systematic use of 4D technologies on construction projects, Malaysia construction industry has yet to embrace this 4D CAD technology. The aim is to explore the acceptability of 4D as a planning and control tool during construction phase of project life cycle. Surveys and semi-structured interviews were carried out on 169 respondents comprising of the clients, local authorities or regulatory bodies, contractors and consultants. The responses obtained indicate that 96.3% acknowledges the application of this new 4D technology as a useful tool with good potential to mitigate delays especially in relation to visualization, analysis and communication during construction. Based on the outcome of the study, it is recommended that financial and technical support be made available before its actual implementation can be realized.

Keywords: *Malaysian construction industry, 4D, visualization, communication, mitigate delay*

Introduction

The problem of delay in construction industry is a global phenomenon and the construction industry in Malaysia is no exception (Abdul-Rahman, H., et al.,2008, Odeh, A.M. and Battaineh, H.T., 2002, Mezher, T.M. and Tawil,W., 1998). Sambasivavn,,M. and Yau,W.S., 2006, Alaghbari, W.et al., 2007 look at the problems causing delays in Malaysian construction industry from the viewpoints of three major constructions practitioners i.e. clients, consultant and contractors. They found that although most of the top ten causes of delays are caused by the contractors, but there are delays that causes by the consultants and clients. Survey carried out by Sambasivavn,M. and Yau.W.S,. 2006 shows that No. 1 ranked cause of delays is contractor improper planning follower by contractor's poor site management, while Ayub,A.R. et a.l, 2007 also claims that ineffective project planning is one of the common cause of delays. Other

common causes of delays are inexperience contractor or consultant , financial problem, slow decision making, lack of communications between parties and lack of manpower, equipment and materials .

In the current practices of project planning and control in Malaysia, as enhanced by Ganah, A.A. et al. (2005), the most common methods and tools used for communication between design and site teams are traditional methods and tools such as 2Dimentional (D) drawings, face-to-face meetings, written statements, telephones and fax which our construction practitioners are accustomed to and find easy to use. Problems often arise with those related to clashes between services systems caused by use of electrical, mechanical and structural entities for each element on 2D drawings. In this regard, it is quite common when joints or junctions are mistakenly identified as a clash between two elements such as electrical lines, air-conditioning ducts, water pipes etc. Misinterpretation on entities and discrepancies on dimensions are inevitable in project implementation undertaken by a diverse team representing different disciplines, educational backgrounds and goals; and this includes clients who are usually a non-technical people who usually have difficulties in *'reading'* the drawings leading to the misinterpretation of the design as a whole.

The existing technology and processes employed to deliver those practices in Malaysia are proven inadequate communicating and addressing the increased complexity of projects and incessant market demand for shorter construction time-scales (Allen, C. and Smallwood, J., 2008). As projects get more and more complex, the issue of constructability becomes more important. Constructability is a project management technique for reviewing construction processes from start to finish during pre-construction phase.

Allen, C. and Smallwood, J. (2008) suggests that by analyzing and identifying a few key areas in the process and communicating that in a way that is understood by all levels of a project team including the client, the construction industry will be able to not only reduce the occurrence of delays on projects, but also improve the working practices and most importantly, the efficiency of their operations, thereby maximizing the profit on projects.

Thus there is a need for a new tool that is easily understood by all project members including non-technical stake holder . With this new tool all members can sit down together to

plan, control and find solution to the problems. When the members understand the problems they can together contribute into finding the solution and at the same time more willing to share the risks.

In the developed countries, 4D models have been used by planners, designers and engineers to analyze and visualize construction projects and have been shown to have benefits over processes that span the entire lifecycle of a project such as collaboration with clients and other project stakeholders (Kahkonen, K. et al., 2001; Fischer, M. et al., 2001), making design decisions, assessing project constructability (Anumba, C.J. et al., 2005), identifying spatial conflicts in construction, developing cost estimates and managing resource requirements (Akinci, B. et al, 2003, McKinney, K. and Fischer, M., 1997).

Based on the results and proofs obtained from prior researches, the application of this VR technology is anticipated and hoped to be able to improve our current practices of project control not just to become more efficient in practice and to be as advance as those practiced abroad, but it is also expected to overcome or to at least reduce potential/ unforeseen delays on Malaysian construction sites. However, Malaysian construction industry has yet to embrace this 4D Computer Aided Design (CAD) technology. There is indeed an urgent need to introduce and highlight to construction stakeholders: project sponsors, consultants, builders etc. what this 4D technology or model planning tool is all about, what it does and can offer, and to find out how they perceive its applications should it be implemented? . The objective of the study find out the acceptability of 4D planning tool as a to tool to mitigate delays during project control among construction practitioners focusing on the construction phase of project life cycle.

Current Construction Project Control in Malaysia

Currently in Malaysian construction industry clients' requirements are still being presented in terms of paper-based working drawings i.e. the 2D drawings and a project schedule that links different construction activities on the basis of these working drawings (Chau, K.W. et al. (2005)). In current practice, site progress is being monitored as and when on a day-to-day basis according to these 2D drawings and the intended project schedule, where physical activities

are being controlled and decided upon during periodic site meetings and ad-hoc sessions. At norm, design is bound to be altered as the work progresses on site (due to change in decision by the end-users or unforeseen site constraints); following which these 2D design drawings and other affected detailed drawings are revised and re-issued to all parties accordingly.

In Malaysian construction domain, 3D CAD software is starting to become the design tool of choice catering to the architecture, engineering and construction industry, especially AutoCAD, Revit and Microstation. 3D models depict the geometry and various aspects of physical objects, can be shaded and rendered to view as original building, and are dynamically visualized with computer graphics, thereby facilitate better communication between various parties involved in the project and the future owners. This technology is highly appreciated in offering impressive 3D views to clients on the proposed building to be built during planning stage and also enables construction practitioners to '*walk-through'* the model of the intended building, giving due satisfaction on what to be expected should it be accomplished.

The Microsoft Project (MS Project) is a project planning and scheduling software produced by Microsoft as a tool to assist construction practitioners especially the project managers to plan, monitor, control and track project status, activities, detailed costing and resource allocations at any point of time during its implementation period in order to achieve the organization's strategic and business objectives. The project schedule produced by this software is commonly known as the *"*Work Programme*"* is the main scheduling tool used for project monitoring by government agencies e.g. the Public Works Department (PWD) nationwide and is also observed to be the most commonly used tool besides Gantt Chart among other construction practitioners in the industry.

4D Technology

4D Computer Aided Design CAD is a planning tool that users can use as an alternative to conventional bar chart schedules or CPM networks for project planning and control (Koo, B. and Fischer, M., 2000). 4D model (3D CAD + Time), visually demonstrates building components being built according to the sequence of the original building construction. As 4D models communicate the schedule as object within the graphical model, the temporal and physical

aspects of the project are inextricably linked and increases the possibility of detecting unanticipated problems beforehand by viewing the 4D model.In other words, the 4D model shows the 3D CAD models of project components being constructed step by step with the progression of time (Koo, B. and Fischer, M., 2000). Additionally, 4D model enables construction practitioners to '*walk-through'* the construction sites at different time intervals and helps to alleviate the misinterpretation/ misunderstanding by clients who have limited ability to visualize or interpret 2D design, leading to design amendments at later stages of the construction process (Sulaiman, M.J., 1996). Dawood, N. et al. (2002) further claims that in 4D models, project participants can effectively visualize and analyse problems regarding sequential, spatial and temporal aspects of construction schedules, following which, Sikka, S. (2007) adds on that by rehearsing construction progress in 3D at any time during the construction process, this 4D technology has the potential to shorten project duration time, improve productivity, reduce costs and avoid rework during the construction phase.

Methodology

In this study, a survey exercise and semi-structured interviews were carried out to determine the perceptions or acceptability of 4D application as a tool to mitigate delays during construction.The questionnaires for the intended survey and semi-structured interviews were prepared based on past literature reviews and were produced in such a way to achieve the objectives of the research.The sampling method used in this study was stratified by convenience and snowball sampling. The questionnaires were divided into four (4) sections i.e. demographic, knowledge on planning tool applications, perceptions towards the newly introduced 4D planning tool based on a respondents model of 4D CAD software demonstrated prior to the survey and causes of delay

Pilot Survey was carried out was to verify the logic of the intended questionnaires in capturing the factors or aspects contributing to the research objectives and to ensure that questionnaires were adequately understood, not misleading. After the pilot survey the questionnaire was refined accordingly. The survey questionnaires were printed in bi-language i.e. English version in black and Bahasa Melayu version in blue..

The respondents of the survey were 169 construction practitioners from multidisciplinary background comprising the clients (owners, developers), Local Authorities or Regulatory Bodies contractors and consultants (architects, civil and structure, mechanical, electrical engineers, quantity surveyors) with mixed demographic and range of working experiences. They were either in groups of project team members during their scheduled periodic site meetings, individual groups of professionals at their respective offices or formal presentation among groups of technical personnel from government agencies in charge of government projects. During the survey the researcher explained about the objective of the study, followed by a brief demonstration on the operations of the 4D CAD software after which, survey questionnaires were finally distributed to respondents and collected by the end of the session.

The data was analyses using SPSS 13.0 while the results obtained from the semi-structured interviews were analysed by using MS Excel.

Results and Discussion

Demographic information of the Respondents

The respondents were 66.7% males and 33.3% female, 87.6% Malays,8.9% Chinese and 1.9% Indians. By profession, 50.3% are C&S engineers, 22% M&E engineers, 18.9% Architects and 7.5% Quantity Surveyors and they are working with government (42.1%), private 39.6% and semi – government (17%). By sector, 32% of the respondents are consultant, 32% client, 13.7% contractor and 4.6% local authority. There is a good mixture of age group between the respondent; 38.4% are 30 years and below, 24.5% are between 31-40 years, 22.09% are between 41-50 years and 15.1% are above 50 years old. In term of working experience, only 32.1% have less than 5 years working experience while the rest have more than 5 years working experience and 22% have more than 20 years of working experience. With more than 5 years working experience means that the respondents have deep knowledge of their work and know the problems and issues in the construction industry.

Knowledge on the planning tool

2D Application

Based on the overall feedbacks, about 94.7% of the respondents who were familiar with 2D drawings affirmed that the application of 2D served the purpose in terms of their work, out of which about 11.8% used it in 7 days/ week, 39.2% used it in 3 – 4 days/ week, 37.9% used it in 1 – 2 days/ week, whilst the remaining 11.1% did not use it at all in a week. This is best illustrated in the Figure 1.

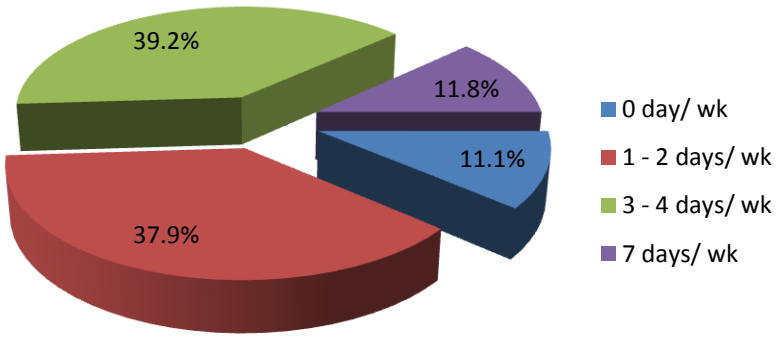

Figure 1: The Use of 2D Drawings by Respondents in a Week

The most frequent usage of 2D drawings, as illustrated in the above Figure 1, is between 1 – 4 days/ week and this must had been reflected by respondentss involved in project implementation stage; governing the planning and pre-construction phases by project team members including Clients, as well as the monitoring of site work progress throughout construction phase by appointed Consultants.

It was also noted that about the same volume or percentage of respondentss had either used this 2D in 7 days/ week or none at all, and this strongly suggested that those related to the former must had been due to their nature of jobs working on site throughout the construction phase eg. Contractors, or directly involved in designing or drafting work, be it from the architectural, civil and structural, mechanical or electrical line of disciplines. On the other hand, respondentss related to the latter must definitely be those at management level who had been exposed and familiar with this tool and were authorized to make decision during implementation stage based on their knowledge and skill. These findings were further clarified in Table 1, outlining the reasons or basis of usage of these 2D drawings.

Table 1 Reasons to Use 2D Drawings by Respondents

	Why do you use 2D drawings?	%
1.	Have to. It's required by scope of job.	53.0
2.	Easier, less expensive and common tool by all team members.	36.4
3.	Use it for the sake of job. But do apply/ use other graphic tool at workplace for self-interest.	23.1
4.	Know other tool. But it's required at this point of time.	21.0
5.	The only tool I know.	13.3
6.	Extra work if use other tool.	3.5
7.	Other reasons.	3.5

In general, the feedbacks captured in Table 1 had apparently justified earlier discussions and further exposed the whole scenario of what is actually taking place in the current practices of project control in relation to these 2D drawings. For example, more than 50% of respondents had committed to use these 2D drawings because they had to and required by respondents' scope of jobs.

Microsoft Project (MS Project)/ Primavera Application

Similarly, based on the overall data collected from this survey exercise, about 96.0% of respondents who had used MS Project or Primavera asserted that the application of MS Project or Primavera served the purpose in terms of their work, out of which about 3.0% of respondents committed to have used it in 7 days/ week, 16.8% used it in 3 – 4 days/ week, 51.5% used it in 1 – 2 days/ week, whilst the remaining 28.7% did not use it at all in a week; as illustrated in the following Figure 2.

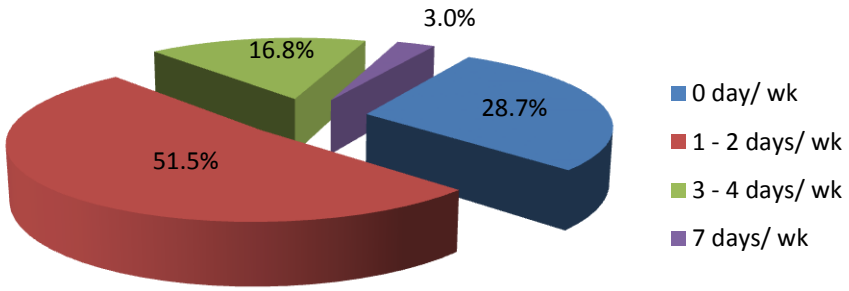

Figure 2 The Use of MS Project or Primavera by Respondents in a Week

Comparing Figure2 and Figure 1, the use of MS Project or Primavera was observed to be in quite the same demand as the 2D drawings from the view point of project implementation aspects. The feedbacks from respondents had demonstrated a total volume of 80.2% of respondents applying the MS Project or Primavera in 1 – 4 days/ week, whilst about 77.1% of respondents were noted to be using the 2D drawings within the same duration.

From Table 2, about 69.6% of respondents had identified the use of MS Project or Primavera as a tool to monitor and control physical work progress on site, whilst 58.8% and 46.1% of these respondents affirmed the important use of this tool in the evaluation of overall project performance as well as producing work schedule for a given project respectively.

Table 4.2 Reasons to Use Microsoft Project/ Primavera by Respondents

	Why do you use Microsoft Project or Primavera?	%
1.	To monitor and control physical work progress on site.	69.6
2.	To evaluate the overall performance of a project (delay or ahead of time).	58.8
3.	To produce work schedule or construction plan for a given project.	46.1
4.	To manage resources and financial updates of an ongoing project.	25.5
5.	Other reasons.	2.9

In conclusion, the basis of usage of MS Project or Primavera had clearly identified the important functions of this planning tool among which were, to produce work schedule or construction plan in order to effectively monitor and control physical work progress on site, and to also evaluate the overall performance of a project; thereby allowing practitioners to anticipate the revised completion time of such project (should there be any delay).

3D Application

It was noted that about 67.6% of respondents who had used 3D acknowledged the application of 3D as being a "must" in terms of their work, out of which about 31.9% of respondents had rated their knowledge about 3D as "Very Poor" to "Poor", 43.5% of respondents rated their knowledge as being "Good" to "Very Good"; whilst the remaining 24.6% of respondents admitted themselves as being "Not Sure" about 3D. This is illustrated in the following Figure 3.

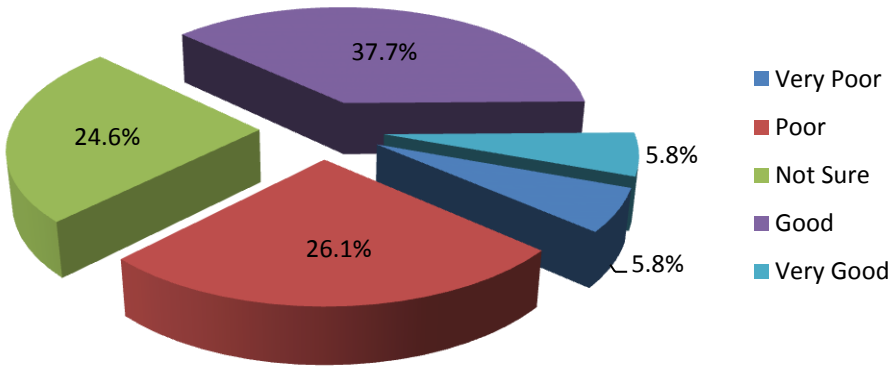

Figure 3: The Rate of Knowledge about 3D of Respondents

The above illustration had confirmed that the presence of 3D technology had been acknowledged in the industry (though had not been considered in the current practices) but the use of this tool is still at the interest of personal or selected professional level. This is due to the fact that 3D is seemed to be of minor or less importance to the industry as compared to the 2D drawings and MS Project/ Primavera in regards to project implementation purposes.

Perceptions Towards the Newly Introduced 4D Planning

The respondents' perception to this newly introduced planning tool technology is conducted in a form of open-ended questionnaires by a simple and direct question on whether it is useful or not to be applied in the current practice. 96.3% of the overall respondents perceived this tool as a useful and worth using tool and they could be used as a visualization tool, analysis tool and communication tool

Visualization Tool

More than half of the responses indicated that this 4D technology is worth and useful as a visualization tool. Their answers are generalized as follows:

1. Facilitates project monitoring.
2. Able to obtain clearer picture and description of the work done.
3. Able to visualize progress throughout the project. Progress can be seen visually on the dates required.
4. Easy to make explanations.
5. Produce better visual presentation and simpler in operation.
6. Able to see real progress. With 2D, sometimes we overlook or have some items unnoticed.
7. Facilitates the planning aspects and construction work.
8. Better visualization for problem solving.
9. Able to resolve problems associated with the construction process.

Kanagasabapathi, B. et al. (2004) claimed this 4D visualization tool is useful for visualizing the construction site status, the progressing work at any specified time as well as the construction process in sequence, where it also assists construction planners to decide on an alternative sequence for a quicker construction by enabling visualization of the details of the work at any point of time. These comments have also enhanced some other literature reviews in the past among which are; 4D CAD as a tool to assist in the construction planning process (Heesom, 2006), as an explanative visualization tool to explain designs and describe work packages (Liston et al., 2001) and also as a visual decision support tool for quick identification of problem areas (Liston et al., 1998).

An Analysis Tool

Among all the feedbacks provided by respondents, the following responses on 4D being a useful analysis tool have been clustered and summarized as follows:

1. Able to speed up the process of a project. Reducing construction cost.
2. Able to improve project performance and hence, able to overcome project delays and excessive costs.
3. Resolve project issues in a short time. Saves time.
4. Assist in the control of delay and reduce the EOT.
5. Wastage of cost can be avoided.
6. Should be encouraged – relevant Clients should have started training their staff last five years.

The above comments which were purely based on spontaneous responses from respondents have apparently enhanced the findings from past literature reviews among which are; 4D simulation as a medium for the evaluation of alternative construction schedules (Vaugn, 1996) to assess its executability (Koo, B. and Fischer, M., 2000) and their logic (Songer, 2005); and also as a strategic decision support system for practical use to manage construction schedules (Dawood et al., 2005).

Although majority of respondents have not been exposed to this new technology, their comments have definitely proven those findings mentioned above, and have further justified some others discussed in past researches such as on how 4D facilitates the review of developed schedules in order to determine potential mistakes (Songer, 2005) at which it allows the exploration of *"what-if"* scenarios where problems can be identified in the early stages of project planning (Kanagasabapathi, B. et al., 2004).

In this regard, planners are able to practice *"what-if"* analysis to compare several planning options in order to select a better strategy (Chau et al., 2005) in mitigating the impact of the change or unexpected event and recovering the delay (Coyne, K.T., 2008). In addition, these 4D simulations can also assist in reducing costs to the project by detecting problems (Koo, B. and Fischer, M., 2000), halving the waste costs associated with a construction project (Webb, 2004) and has also been advocated as a training tool for inexperienced planners (Jaafari, 2001; Clayton et al., 2002) to identify problems that can be neglected by experienced personnel in the traditional schedule formats (Koo et al., 2000).

A Communication Tool

The remaining of the feedbacks was very much related to the aspect of communication between various parties involved in a project. These are summarized as follows:

1. Contractor, Consultant and Client can easily understand about the project based on the 4D plan. Able to allow the whole team to understand the progress better.
2. Assists in the implementation of project preliminary design, project supervision and project monitoring involving all the disciplines in an integrated manner.
3. Facilitates the implementation of job tasks in terms of co-ordination and visual. Clearer view for installation and proper co-ordination between services.
4. Easier to supervise and co-operate between Client and main-contractor.
5. Able to promote a more efficient planning in construction.

In the context of 4D being a useful communication tool, the above comments have generally highlighted some findings from past related literature reviews among which indicate that an actual 4D model is able to remove ambiguity between visual representations of the construction project as well as communication problems between various parties involved in a project, and thus allows all parties to communicate using the same model (McKinney and Fischer, 1998). In this regard, all participants of a construction project are able not only to inspect 3D model through the project data network, but also to recognize the actual construction progress, to evaluate resource utilization in a specific duration and thus contributes to better resource planning (Chau et al., 2005).

It has also been documented that a 4D model is able to assess and validate a planned schedule's duration, sequencing or critical path, and also assists in the resolution of the communication gap by allowing all parties to visualize project delays (Coyne, K.T., 2008). Additionally, creating a 3D model over time not only has the potential to present ideas to clients in order to promote collaborative working (Fischer, 2001), but also assists in the construction planning process (Coles and Reinschmidt, 1994). In conclusion, based on this survey exercise, the respondents' comments in relation to the aspect of communication in 4D planning have been well justified in accordance to past literature reviews.

Why is 4D Not Useful (Not Worth Using)?

Based on the outcome of the survey, only 3.7% of the overall participated respondents perceived this 4D tool as not useful or not worth using. The feedbacks received are summarized as listed below:

1. Commercially not feasible.
2. Have never tried, just heard and seen.
3. Not sure about its use.

Apart from the above responses, no reason was given by the remaining respondentss who had earlier committed to 4D not being useful in the preceding question. In brief, these responses indicate lack of interest and uncertainty of respective respondentss about this newly introduced technology. No technical remarks were given. As such, no further justification can be made on such outcome.

Hindrance Factors in Using 4D at Workplace

The feedbacks provided by respondents on potential hindrance factors in using this 4D tool at the workplace are generalized as follow:

1. Cost – for the development of 4D at workplace.
2. Skilled resources i.e. knowledge in 4D application which requires training and time.
3. Mindset/ attitude (acceptance by staff).
4. Bureaucracy – bureaucratic factors and system/ procedures in place.

Based on the survey, it was observed that almost half (46.3%) of the hindrance factors provided by respondents were related to cost to get this 4D procured at the workplace as well as cost to provide required trainings to selected staff (44.0%). 8.2% of mindset or attitude and finally, 1.5% of bureaucracy as factors hindering this 4D from being applied at the workplace.

Having the fact that proper trainings and time are deemed required in order to obtain resources with appropriate knowledge in 4D application, skilled resources had been emphasized as the second most important factor expected to hinder this new technology from being applied at one’s workplace.

Mindset or attitude which constituted about 8.2% of the overall hindrance factors had been identified, though minimal, as a factor that would personally affect the users themselves from accepting changes in the current practice, and thus hinder this tool from being adopted at the workplace. And finally, the bureaucracy which constituted about 1.5% of these factors is very common especially in procuring any new technology in any industry nationwide due to the need of justification and policy that needs to be in place prior to its actual implementation.

On the contrary, in reference to past literature reviews, a survey and interviews conducted by Khatib, J.M. et al. (2007) identifies lack of knowledge, lack of continuity of similar work and attitude rather than cost of producing 4D models as the main barriers impacting on the deployment of this technology among the construction planners. Basu, A.,(2007)emphasizes on the learning curve barriers that requires training and many hours of hands-on use in order to get an acceptable level of productivity . In this regard, attitude or mindset plays an important role where one has to be committed in learning this 4D technology to be well-versed in aspects pertaining to the operations or functionalities of this 4D planning tool. Additionally, these factors have also enhanced Sarshar and Isikdag, (2004)'s findings that time and financial losses can be attributed by the complexity in introducing a new system which involves an integration of software.

Performance of 4D Planning Tool as Compared to Other Conventional Planning Tools

70.4% of the respondents stressing the followings as their perceptions on the performance of this 4D planning tool in comparison to other existing conventional tools.

1. Very good/ very impressive.
2. A very useful, integrated and comprehensive tool for project planning and monitoring.
3. Has the potential to help reduce errors/ problems in construction industry by identifying the source of problem(s) more quickly.
4. Able to reduce presence of VO and saves time.
5. 4D planning technology allows us to visualize all aspects compared to conventional tools.
6. Able to produce a higher quality and more advanced construction industry.

Based on the above responses the respondents specifically indicated its advantages in the project monitoring and control aspects by means of visualization. These feedbacks had apparently complemented the overall comments provided by those 96.3% of respondentss who perceived this tool as a useful and worth using tool in earlier session.

These findings had definitely enhanced those obtained from prior researches, highlighting the benefits in terms of time and cost savings gained through the systematic use of 4D technologies on construction projects (Hartmann, T. et al., 2008); particularly helpful in projects that involve multiple stakeholders and those which face space constraints on site (Fischer, M. and Kunz, J., 2004); as well as enabling a diverse team of participants to collectively make decisions on a project and improve the constructability and execution strategies, and thereby identifies design conflicts prior to construction (Khanzode, A. and Staub-French, S., 2006);

However, despite these significant benefits as proven by past researches and as perceived by respondents in this intended survey and semi-structured interviews, to-date Malaysian construction industry has yet to embrace this 4D CAD technology.

Conclusion

Based on the outcome of the study, this 4D planning tool is a very promising planning tool in our current practices of project control and it is expected to be able to assist our construction industry to mitigate or to at least reduce the anticipated delay, or even perhaps to be able to overcome the time usually lost for error detection when using 2D drawings. It is also recommended that a further study on its application is carried out on a real life case study with an estimated cost of above RM1 million (to cater for the procurement and preparation for modellers) i.e. a project starting from its inception stage so that the percentage of reduction in anticipated delay when 4D planning tool is applied can be determined.

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