A Study on Effective Construction Management Utilising CIM (Civil Information Modeling/Management)

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ABSTRACT

The progress of science and technology has been tremendous in last two decades, especially in fields related to ICT. We, civil engineers, are adopting more computerized techniques for a growing variety of applications to increase construction efficiency. However, the historic industry reliance on manual paper records and/or non-integrated electronic systems for archiving has resulted in considerable useful data being lost.

To address these issues the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has been introducing Civil Information Modeling (CIM) in the civil engineering field since 2012 to improve the efficiency and continuity of valuable construction data.

In this paper, we carried out two surveys to explore and evaluate the relationship of the management elements defined by PMBOK so as to identify the critical issue associated with utilizing CIM in the civil engineering field. We employed a network analysis technique for numerical considerations.

BACKGROUND

The efficiency in the release of construction projects within Japan has been stagnant and over-complicated for a number of decades. Even two years after the huge earthquake in Northern Japan on 11th March 2011 there remain a considerable number of re-construction projects as yet to be contracted out. Further, the awarding of the XXXII Olympic Games to be held at Tokyo City in 2020, and current shortages of workers, materials and machines have significant impacts on planned re-construction and infrastructure projects in the foreseeable future.

In contrast, the advancement of science and technology in the last two decades has been significant especially in fields related to ICT, which are driven by consumer demands for continual improvements and features in cell phones, personal computers, internet connectivity and so on (Fig. 1). These data are published by the Ministry of Internal Affairs and Communications.

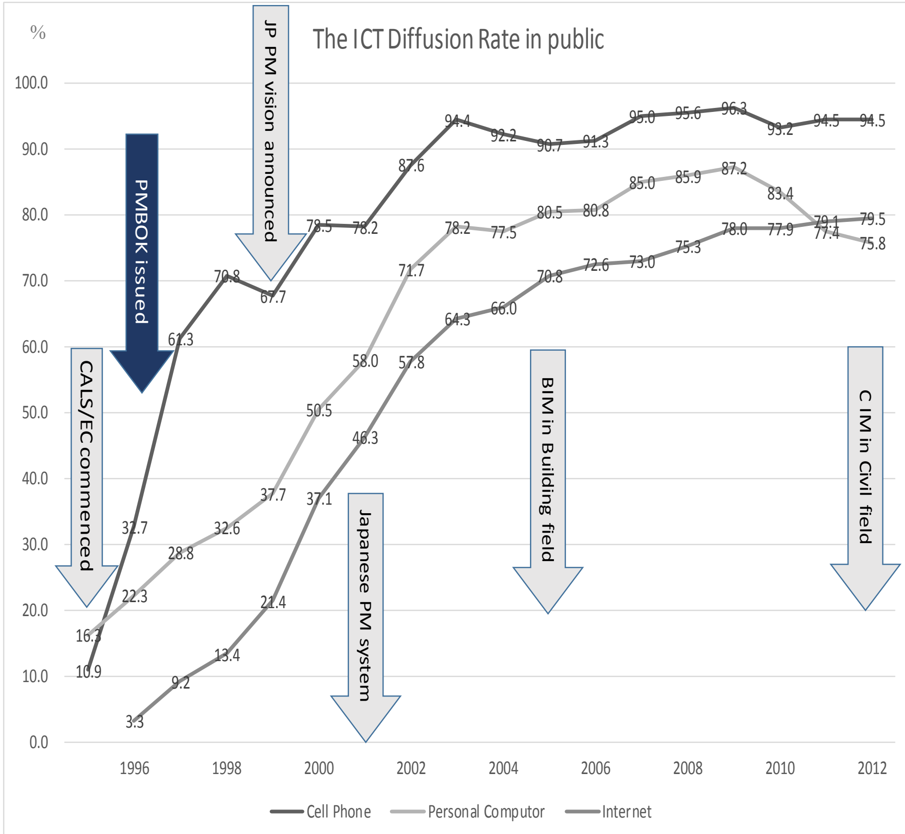

Figure 1. ICT Diffusion Rate and PM system established

The objectives of introducing ICT within the construction industry are to improve and enhance production rates, quality delivered, safety and comfort, as well as ensuring the effective and efficient spending of tax revenues utilized for construction projects. The use of ICT processes to robustly record and store knowledge and data that can be readily retrieved and used throughout a project life-cycle (and indeed even by subsequent generations) is also a significant and major benefit envisaged.

In the building business field the use of 3D-CAD for Building Information Modeling (BIM) has been developed since its introduction in the late 1990s, such that in 2005 some 25-30% of all building projects in Japan used this technology. Continuous Acquisition, Lifecycle Support and Electric Commerce (CALS/EC) has been adopted within civil engineering since 1995, however this has not penetrated into the common management practices to anything like the extent seen in Building projects 20 years after being introduced.

To date little benefits have been evident in the use of ICT in civil engineering other than perhaps in electronic bidding systems to prevent controlled or pre-agreed bidding. Even where ICT has been extensively used, and electronic archive data is available, this has only been stored locally within the contractors data-base. Consequently the potential benefit of this data for research, knowledge transfer and future similar projects is lost, or at least certainly not optimized.

Due to the ever tightening budgets for public construction projects, and the limited (almost stagnant) effectiveness of CALS/EC, MLIT commenced its study on the introduction of CIM for Civil engineering in 2012.

PURPOSE

Although eight pilot projects were carried out in 2012, results have as yet to be formally published making definitive commenting on the benefits of CIM in the civil engineering field difficult. We can however deduce that there may be fundamental problems to be uncovered within the construction processes, as focus and effort was largely spent on implementation during design. In this paper we focus on the likely effectiveness of CIM introduction within civil engineering from a construction management perspective.

METHODOLOGY OF STUDY

The lifecycle of construction projects comprise several phases, namely: planning, investigation, design, estimation of cost, bidding and contracting, construction and operation/maintenance. As each of these phases is typically bid and awarded separately, information at each stage may be isolated or at least not fully transferred. The key objective in adopting CIM throughout the entire project life-cycle is to minimize, control and manage the overall “risks” likely to be encountered. In our evaluations and considerations, we have therefore adopted the management elements associated with risk management as defined by PMBOK to identify the potential critical issues when CIM is applied within civil engineering. In our analysis, we have utilized the Construction Extension of PMBOK 3rd edition which defines 13 elements, 9 of which are standard and applicable to all projects, but safety, environment, finance and claim are specifically define in addition as applicable to construction projects.

We conducted our two surveys amongst construction management professionals worldwide (typically working for contractors and with generally at least 15 years’ experience, age 40 above within the civil industry) to gather data on the inter-relationship between the management elements adopted and most reflective/representative of civil engineering projects (i.e. 12 of the elements as ‘integration’ was excluded). We designed matrixes for the relationship which facilitate the evaluation of the effect of the relationship both horizontally and vertically. In the initial survey, participants were asked to score the 8x8 matrix using “1” or “0” to record a strong relationship or not.

		Cost ①	Time ②	Communication ③	Quality ④	Procurement ⑤	Human Resource ⑥	Scope ⑦	Risk ⑧
Cost	①	0	34	9	34	34	27	8	27
Time	②	33	0	12	21	27	25	14	13
Communication	③	11	7	0	16	21	16	16	20
Quality	④	34	21	17	0	19	34	8	16
Procurement	⑤	29	25	25	14	0	8	8	9
Human Recourse	⑥	32	19	19	22	1	0	22	18
Scope	⑦	12	14	12	10	7	16	0	11
Risk	⑧	27	17	19	21	11	19	18	0

Effecting Direction

		Cost ①	Time ②	Communication ③	Quality ④	Procurement ⑤	Human Resource ⑥	Scope ⑦	Risk ⑧	Safety ⑨	Environment ⑩	Finance ⑪	Claim ⑫
Cost	①		47	30	46	45	40	28	38	37	38	36	37
Time	②	44		32	31	38	34	31	35	35	30	23	30
Communication	③	17	22		23	19	32	23	29	25	21	20	30
Quality	④	44	40	29		40	41	29	30	25	22	26	26
Procurement	⑤	41	34	32	38		28	28	25	17	20	38	18
Human Recourse	⑥	35	30	27	30	17		30	26	28	19	30	28
Scope	⑦	26	25	25	22	16	26		21	25	24	21	21
Risk	⑧	39	38	37	33	31	36	30		41	33	28	37
Safety	⑨	37	33	33	19	17	40	30	36		27	21	17
Environment	⑩	32	22	25	25	23	31	25	29	26		15	25
Finance	⑪	39	23	24	26	35	31	22	32	24	23		32
Claim	⑫	35	33	40	37	20	33	28	35	23	31	23	

Effecting Direction

Figure 2. Survey Result (Total Cell Scores)

The subsequent survey adopted the 12x12 matrix with participants given the three score grades; "2" (strong), "1" (medium) & "0" (minimal) to better identify the strengths of relationships between the management elements. In total, 42 and 24 responses were returned for the 8 and 12 element management matrixes respectively.

ANALYSIS OF MANAGEMENT MATRIXES

The variance in the responses received reflects the independence of the participant's and their respective variety of knowledge, exposure and experience within construction management. Accordingly, we prepared a set of summary matrixes and summed up the scores for each cell whereby the larger number reflects the stronger inter-relationship as shown in Fig. 2 above.

We then calculated on the basis of the variances ("distances") of the individual cell scores from the maximum cell score attained to effectively define a base spatial network model for the management element inter-relationship. In this case, the stronger inter-relationships between elements are those closer to "1", with those equal to "1" naturally being the strongest as determined by our surveys.

		Cost	Time	Communication	Quality	Procurement	Human Resource	Scope	Risk
		①	②	③	④	⑤	⑥	⑦	⑧
Cost	①	0.00	1.00	2.36	1.00	1.00	1.26	2.81	1.26
Time	②	1.03	0.00	2.62	1.62	1.26	1.36	2.43	2.29
Communication	③	2.79	2.98	0.00	2.13	1.62	2.13	2.13	1.70
Quality	④	1.00	1.62	2.00	0.00	1.79	1.00	2.55	2.13
Procurement	⑤	1.17	1.36	1.36	2.17	0.00	2.43	3.49	2.43
Human Recourse	⑥	1.06	1.79	1.79	1.55	2.06	0.00	1.55	1.89
Scope	⑦	2.83	2.43	2.83	3.40	3.69	2.13	0.00	3.09
Risk	⑧	1.26	2.00	1.79	1.62	2.26	1.79	1.89	0.00

		Cost	Time	Communication	Quality	Procurement	Human Resource	Scope	Risk	Safety	Environment	Finance	Claim
		①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫
Cost	①	0.00	1.00	1.57	1.02	1.04	1.18	1.68	1.24	1.27	1.24	1.31	1.27
Time	②	1.07	0.00	1.47	1.52	1.24	1.38	1.52	1.34	1.34	1.57	2.04	1.57
Communication	③	2.76	2.14	0.00	2.04	2.47	1.47	2.04	1.62	1.88	2.24	2.35	1.57
Quality	④	1.07	1.18	1.62	0.00	1.18	1.15	1.62	1.57	1.88	2.14	1.81	1.81
Procurement	⑤	1.15	1.38	1.47	1.24	0.00	1.68	1.68	1.88	2.42	2.35	1.24	2.42
Human Recourse	⑥	1.34	1.57	1.74	1.57	2.39	0.00	1.57	1.81	1.68	2.47	1.57	1.68
Scope	⑦	1.81	1.88	1.88	2.14	2.85	1.81	0.00	2.24	1.88	1.96	2.24	2.24
Risk	⑧	1.21	1.24	1.27	1.42	1.52	1.31	1.57	0.00	1.15	1.42	1.68	1.27
Safety	⑨	1.27	1.42	1.42	2.29	2.31	1.18	1.57	1.31	0.00	1.74	2.24	2.54
Environment	⑩	1.47	2.14	1.88	1.88	2.04	1.52	1.88	1.62	1.81	0.00	2.77	1.88
Finance	⑪	1.21	2.04	1.96	1.81	1.34	1.52	2.14	1.47	1.96	2.04	0.00	1.47
Claim	⑫	1.34	1.42	1.18	1.27	2.35	1.42	1.68	1.34	2.04	1.52	2.04	0.00

Figure 3. Relative "Distances" between Management Elements (W-F algorism

To further refine our analysis, we identified the hierarchy of influential elements by calculating and adjusting our matrix based on the closeness index for pairs of elements using the Warshall-Floyd (W-F) algorithm. (Fig. 3)

The hierarchy for both the 8 and 12 elements is shown in Table 1. It can be noted in the 8 element hierarchy that "human resource" is elevated to 2nd and "risk" is listed 5th, in contrast to the 12 element survey where "risk" appears 2nd within the hierarchy. Whilst a more detailed analysis on the reasons for this may be necessary, it is likely that "risk" is heavily linked to the additional 4 elements within the 12 element hierarchy.

Table 1. Relative Closeness Index

Relative Hierarchy of Effectiveness			
8 Elements		12 Elements	
Cost	1.00	Cost	1.00
Human Resource	1.09	Risk	1.10
Quality	1.17	Time	1.13
Time	1.18	Human Resource	1.19
Risk	1.26	Quality	1.19
		Claim	1.27
		Safety	1.31
Procurement	1.29	Procurement	1.34
Communication	1.38	Communication	1.36
		Finance	1.36
		Environment	1.41
Scope	1.71	Scope	1.42

Quality, Cost and Time are relatively high in both the 8 and 12 element components as may be reasonably expected, however the 4 additional elements from the Construction Extension of PMBOK 3rd edition only appear with middle and low rankings.

Clearly the interactions and complexities of management when considering the 12 elements reflects better the emphasis and concerns of the experienced managers who participated in our survey. In particular this reflects the trend towards risk based management techniques and ever increasing risk management requirements within project specifications.

The availability and use of suitable risk management tools to facilitate construction managers in fulfilling required tasks and tracking status are therefore of considerable value. As risk management is applicable to all stages of a project life cycle, we considered CIM as potentially an effective tool in the project risk management armory. Certainly as conceptualized in Fig. 4 below, the potential to model and input risk data through each project stage is evident, and with the benefit of a linked cohesive and robust centralized record, the transfer of 'residual' risk through each phase could be effectively controlled and managed.

The benefits of CIM to ensure the continuous transfer and feedback of knowledge and data are clearly evident, but does this arrangement fit the Japanese construction industry as it stands and operates today? Due to enactment by official notice of the Japanese Ministry in 1959 each separate phase of almost all public works are contracted out independently, and this practice continues even now. Only around 20 in every 10,000 MLIT projects are tendered and awarded on a 'design and construct' basis as well as some smaller projects awarded through local government offices. The 'design and construct' format however may still exclude elements such as planning, operation and maintenance.

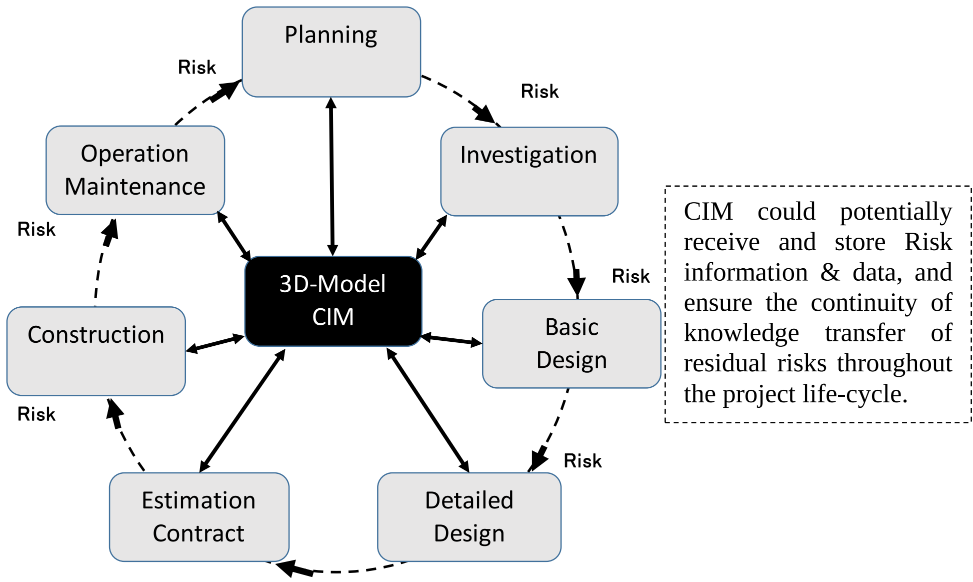

Figure 4. Risk Management Model using CIM

Such contract arrangements do not in themselves facilitate full life-cycle risk management as potentially each construction organization will establish its own risk management data in isolation on award and signing of the contract. To utilize CIM robustly and effectively, it is clear that the MLIT, local Government offices, or indeed Client organization must take the lead and initiative for overall management and coordination. They must ensure data formats, data transfer arrangements etc. are clearly specified within each stage contract such that all data can be stored, unified and managed within their central CIM database. Similarly they must ensure the clear transfer of risk knowledge and residual risks through each contract award to ensure the cohesion and value of transferred data is maintained. Without the Client organization taking the lead with a view to ultimately gaining the full benefits CIM can provide (for risk management and equally management of other elements), its introduction in the civil engineering field will continue to fall short of potential.

CONCLUSION

The Integrated Project Delivery business model initiated in the US utilizing BIM as a key coordination and management tool is widely adopted by Architects, Engineers, Contractors, Clients and all stakeholders in building projects. This has been seen to provide considerable benefit to stakeholders in identifying current, future and even hidden risks early in the processes such that they can be strategically mitigated or even avoided and eliminated.

Since MLIT's introduction of the same concept through the CIM initiative since 2012, similar wholesale benefits to the industry should be evident. However, initial feedback from pilot projects limit merits to the avoidance of reinforcement and utility clashes, clarity on pre-operation workers scopes and tasks in jointly owned processes, and other similar low key benefits which were not the key targets behind the CIM introduction.

CIM is just one of many tools, but certainly it is a key asset in ensuring valuable data from civil engineering projects is robustly stored and utilized for the benefit of all parties concerned. This requires a move away from (or at least parallel) storage on media such as CD's through CALS/EC enforcement where already in Japan some 15 years' of data has been stored. The availability of this data is generally either unknown or inaccessible to those seeking to improve the industry through innovation. Our study however shows that for CIM to be effective, reliance cannot just be placed on the interface interaction between contracts if continuity is to be achieved and the most value obtained. Government Agencies or Client organizations must take the lead in driving CIM forward, or establish packaged contract systems such as Public Private Partnerships that can support it.

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