COLLABORATION IN BUILDING INFORMATION MODELLING: AN APPLICATION OF GAMING THEORY

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ABSTRACT

There is vitally significant evidence to show that certain indices of project performance in construction are vulnerable to fragmentation of design, procurement, construction and operations' processes. Some studies have argued that fragmented processes often weaken frameworks for sustaining objectivity and value integration between project stakeholders. This situation is responsive to effective communication, collaboration, thorough integration and passion for objectivity in data sharing and information management between key players. Three Game Theory models (Prisoner's dilemma, pareto optima and hawk-dove) are used (and herein reported) to mirror certain implications of *players'* actions in BIM environment. Players' actions in BIM are categorized as *null, partial* and *full* cooperation to engage the ethos of integration in BIM. These model scenarios are argued to show that when BIM is partially adopted, benefit is relative to compliance with principles and drivers of positive outcomes – i.e. the party that complies with certain fundamental principles will benefits more than partially complaint parties, while the non-compliant party looses. However, when BIM is fully adopted, all parties benefit more than when BIM is either partially adopted or not adopted at all. Conclusions are drawn on the implications of adopting and deploying BIM in the industry - BIM means a lot to the industry; there could be tragic consequences when the industry fails to adopt BIM and allied innovations in the era when digital technology is revolutionising other industries. Recommendations are made on areas of further research.

Keywords: Building Information Modelling, collaboration, game, hawk-dove, pareto optima, prisoners' dilemma.

INTRODUCTION

In the past decades, there has been significant apprehension over the implications of failures of process in project development systems. This concern has been given widespread publicity across world regions; and yet triangulated between different classes of stakeholders. Opinions that are portrayed in several studies are that clients are dissatisfied with contractors and consultants, and some consultants are dissatisfied with contractors and clients, and also that some contractors are dissatisfied with some clients and consultants. Hence, bulks of complaints often overheat project governance in the industry to an extent that considerable attention of government has been evident. Many authors have used the renown industry reports in the United Kingdom (e.g. (Egan 1998; Latham 1994)) to benchmark public concerns regarding project performance in the UK and in other parts of the world. As this challenge seems universal – similar concerns have also been reported by the Hong Kong Housing Authority (HKHA) (2000), several other studies (Acharya et al. 2006; Al-Momani 2000; Palaneeswaran et al. 2006; Ryd 2004) have hinged this situation on the implications of fragmented processes on practice conventions in the industry. The limitations of fragmentation is not limited to design, but rather of whole-life performance of infrastructures, involving design, procurement, construction and facilities operation and management. According to (Koskela 2000), the construction industry is one of the few industries where attempts to overcome fragmentation of processes are still weak and of limited adoption outcomes. Due to the strategic importance of construction in the larger economy, other industries are worse off when there is a wide gap between public expectations and the reality of project performance. Regrettably, clear evidence from literatures have been used to elicit how process fragmentation often lead to conflicts and disorientation, project failures, clients' dissatisfactions, poor professional integrity, variability in costs and contract periods, and poor quality of projects (Al-Momani 2000; Kagioglou et al. 2001).

The adoption and deployment of certain tools of information technology (IT), especially those that support objectivity, artificial intelligence and integrative processes, have been suggested as an important way out of this challenge. Although, implementation of integrative models of IT tools is not strange to the construction industry, however the some tools being used (e.g. entity-based Computer-Aided Design (CAD)) have not been able to deliver most satisfactory results. This is because entity-based CAD and allied applications still support fragmented processes. Individual stakeholders only design and input project data independently, and without considerable commitment to the interests of other stakeholders. Moreover, apart from the structural limitations that prevent entity-based CAD applications from triggering the needed drivers of success in integrated design systems, these applications also have major challenges with spatiality, temporality and information flow.

Many reports have identified potential benefits of building information modelling (BIM) in addressing both the limitations of CAD and revolutionising entire project development and management processes. According to (Luciani 2008), the revolution caused by BIM, though new and not fully conceptualized, are truly radical and have started rebranding the structure of construction markets. However, some limitations also exist in the realization of all BIM promises. According to (Gu et al. 2008; Succar 2009) some vital attributes are still missing: (1) its adoption is still slow, (2) there is not yet a definitive understanding of all disciplines regarding BIM capabilities, (3) and what is in new opportunities for their roles in BIM-propelled revolution, and; (4) the comprehensive understanding of market drivers of clients' interests in BIM. Regardless of those, some studies have proved that BIM serves as digital information repository wherein stakeholders are able to integrate, share data and values to create object-oriented designs and overcome some of the limitations of entity-based CAD. Importantly, collaboration has been identified as a significant attribute of BIM that drives project performance

(Gu et al. 2008 ; Lottaz et al. 2000). This study mirrors collaboration in BIM in three gaming scenarios, namely; prisoner's dilemma, pareto optima and hawk-dove. Possible outcomes of these gaming scenarios are iterated in BIM environment to derive workable lessons on different streams of BIM adoption.

OBJECTIVES

The objectives of the study are as follows:

(1) To review the advantages of collaboration in integrated systems involving design and construction processes, and;
(2) To predict the implications of collaboration in different gaming scenarios

COLLABORATION PLATFORM AND BUILDING INFORMATION MODELLING

BIM means different things to different people and disciplines. Some of these attributes have been summarised in the literature chat that is presented below in Table 1. Surmising those propositions, BIM evidently represent a dynamic platform for interoperating digital information on construction projects, including virtual repositories for generating, sorting, sourcing, sharing, updating and extending all forms of project specific data across relevant disciplines that are involved in integrated systems. (Aranda-Mena et al. 2009) have summarized some contemporary and comparative opinions regarding BIM definitions and concepts. Arguably, BIM technologies, techniques and skills are laterally different from and more productive than conventional CAD applications. Some case studies recently reported by (Aranda-Mena et al. 2008; Fusell et al. 2007) indicate that success is not guaranteed in all BIM platforms – certain attributes must be met. Some studies have also identified certain challenges against full realization of BIM potentials. These include the need for standardized models for the development, adoption and deployment of appropriate software applications to drive integrated processes in systems, and how to stimulate genuine willingness and commitment in stakeholders to facilitate the realization of BIM potentials through thorough co-operation, collaboration, value sharing and effective communication.

As BIM triggers collaboration – a necessity for improved project performance, (Kalay 2001) have argued that collaboration as a phenomenon is not limited to superficial or semi-structured interactions between project team members, rather it involves uniformity in the nature of data being created and transmitted in integrated systems, including compliance with structured mechanisms for servicing digital systems. While investigating the drivers of effective collaboration in virtual teams, (Nikas et al. 2007; Rezgui 2007) concluded that partial adoption of integrated technologies and wanton compromise of the ethos of collaboration could trigger tragic outcomes on project expectations.

Major Attributes	**Simple definition of attributes**	(Lee et al. 2006)	(Aranda-Mena et al. 2009)	(Heesom and Mahdjoubi 2004)	(Tse et al. 2005)	(Fusell et al. 2007)	(Marshall-Ponting and Aouad 2005)	(Kalay 1998)	(Leung et al. 2008)
Inter-operability	Open and compatible exchange of digital information between all design stakeholders	✓	✓	✓	✓	✓	✓	✓	
Collaboration	Consistent willingness of all parties that are involved in BIM processes to share standardized information, use compatible tools and take responsibility as appropriate	✓	✓	✓	✓	✓	✓	✓	
Objected-oriented design	The use of virtual objects to represent design variables	✓	✓	✓	✓	✓	✓		
Simultaneous Access	Unlike multi-window systems used in conventional CAD, it means interoperable and concurrent access of all users to project database, regardless of their geographical separation.	✓	✓			✓			✓
Project visualization	Visualization of designs in multi-dimensional spatiality, including the use of 3D and object models.	✓	✓		✓	✓	✓		✓
Auto-quantification	Automated generation of embedded quantity data for procurement purposes – this is not just scaling and dimensioning, but it includes integrated instantiation of graphic and non-graphic data which can be used for many integrative purposes.	✓		✓	✓	✓		✓	
Value-audit	Extensibility of model objects into both *soft and hard* structured value engineering and management concepts		✓		✓	✓			
Integrated systems	Combination of open systems that allow multi-disciplinary access, storage, design, engineering, estimating, simulation, planning and co-ordination	✓	✓	✓		✓	✓	✓	
nD-modelling	Multi-dimensional modelling, including architectural, engineering, procurement, construction planning and co-ordination, and other activities involved in whole life cycle management of facilities	✓	✓	✓	✓	✓	✓	✓	
Co-operation	Conscientious intent to selflessly participate in integrated systems, including surrendering, delivering, extending and protecting the integrity of digital information and systems, without wanton compromise at any stage	✓	✓	✓	✓	✓	✓		

Value integration	Recognition, understanding and unification of diversified multidisciplinary values, above trade egos and motives that trigger conflict of interest, but rather including the motivation and respect of all professionals involved in the project	✓	✓	✓	✓	✓	✓		
Effective communication	Exchange of compliant and robust digital information in manners that effectively drive the mechanisms of knowledge sharing in integrated systems	✓	✓	✓	✓	✓	✓	✓	
Virtual enterprise	Ad-hoc alliance of independent stakeholders, though geographically dispersed, to collaborate using agile, flexible, fluid, goal focused and web-based technologies to drive the ethos of integrated systems	✓	✓	✓	✓	✓	✓	✓	✓
Integrated Project planning	Extensive application of integrated design and project data for construction planning and co-ordination purposes	✓	✓	✓		✓		✓	✓
Simulation	The use of virtual characters (avatars) to replicate real life occurrences in a BIM			✓				✓	✓
Flexibility	Ease of manipulating higher dimension models to lower dimension models (nD… 5D, 4D – 2D) and vice versa without compromising the robustness, quality and accuracy of graphic and non-graphic context of the models	✓	✓	✓	✓	✓	✓	✓	

Table 1: Literature chart on attributes of BIM

Moreover, (Han et al. 2007) also identified as impediments to effective collaboration in virtual teams, the industry's reluctance to adopt BIM, over-reliance (and the limitations of results thereof) on entity-based CAD and allied applications across disciplines, and the compatibility of these applications with integrated systems. Consequent upon this argument (as above), there are three possibilities in collaboration, and these will be used in later discussion as follows:

1. Perfect cooperation between parties to engage in all the ethos of collaboration in BIM environment.
2. Partial cooperation between parties to engage in the ethos of collaboration i.e. few components of integrated systems may have all the requisite facilities and engage in BIM deployment while others do not have the framework to drive the system.
3. Outright lack of cooperation by stakeholders to collaborate. This scenario shall be referred to as null cooperation in the later part of this study.

GAME THEORY AND COLLABORATION IN CONSTRUCTION

Researchers often use Game theory to demonstrate the philosophies of social and system dynamics in team practices (Lane 1999). The focus of these mechanism is to predict possible outcomes of behaviours when team members, also know as *actors* or *players* choose to behave within certain options of specific scenarios of cooperation. Although it is commonly used in behavioural sciences, game theory philosophies have been used to define construction situations, both as in life cycle processes and intrinsic forms of cooperation in collaboration scenarios (Gruneberg and Hughes 2006; Wübbenhorst 1986). (Benbunan-Fich and Arbaugh 2006; Brandon et al. 2005) have also demonstrated the relationship between collaboration and cooperation. Whilst *Gaming* philosophies have been used mainly on issues relating to conflict (McCain 1999), (Vaaland 2004) argued that a good way to explore collaboration scenarios is to mirror them through conflict situations. Therefore, rather than using game theory to define cooperation only in dispute scenarios as it is being popularly used in construction, it can also be used to model other scenarios where cooperation is an ultimate factor. This is not only because conflict is an inverse of cooperation, both concepts share identical variables (e.g. there are limited *IF* options in both philosophies). Other empirical studies by (Auger et al. 1998; Sheehan and Kogiku 1981) have also established the relevance of three forms or lenses of *Gaming* in construction, viz; (1) Prisoner's Dillema (2) Pareto-Optima (3) Hawk-Dove. Some examples of limited *IF* options (otherwise called 'conditionalities') which underpin *Gaming* philosophy in those lenses as highlighted above are:

(1) members actions affect the team definitely

(2) members have only two directions of strategic actions – to cooperate in collaboration or not

(3) only two player-positions are feasible.

The applications of these concepts in BIM integrated system are discussed below.

Prisoner's Dillema

In prisoner's dillema gaming model, players only have two options as possible outomes from corresponding number of negative options. On the one hand, the options are that both actors either cooperate or refuse to cooperate with extrinsic and objective goals. The correponding goal of these options is to tolerate risks and its consequences (if they both cooperate) or reduce immediate risks (if either party decides to sabotage coopration), while future effects that associate with those risks become masked in the short run or result into massive negative consequences in the long run (if both parties decide to sabotage cooperation). Moreover, the actions of each player is tailored towards maximising self interest, with or without considering the implications of such actions on the other party. When both players cooperate, they are both better-off. However, when only one party cooperates and the other does not, the party that refuses to cooperate gains more at the dentriment of the party that cooperates. When both parties refuses to cooperate, they both benefit on the basis of individual interest, relative to what each party have invested into the common course of action. Figure I illustrates prisoner's dillema logic.

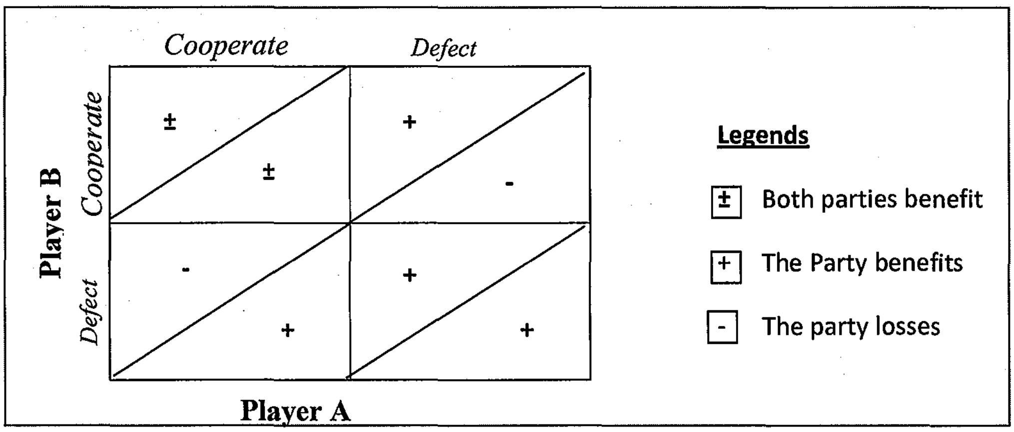

Figure I: Gaming logic for Prisoner's Dillema model

Pareto-Optima

Pareto-optima is popularly conceptualised based on the result of the early works of an Italian economist and sociologist, Vilfredo Pareto (1848 - 1923). It is often used in gaming scenario to demonstrate effective allocation of resources. In practice, both parties are well-off when they cooperate maximally. Apparently, the party that least contributes to common course initially benefits more in the short run than the other party who presumably contributes more than the other party at the initial stages. However in the long run, the least contributing party (non-cooperative party) will emerge as the most valuable contributor, even though the system appears as stable and balanced when all players benefit evenly. Another important point to note in the model is that there is no way a party will be better-off the common course without the other party being worse-off. This is because, on the one hand, the party that cooperates more than the other benefits more, while the party that lease cooperates is worse-off. When they both defect, they are both worse-off. On the other hand, if things fall apart in the course of cooperation, the party that would have benefitted if the cooperation had worked out well will be worse-off. Figure II illustrates pareto-optima logic.

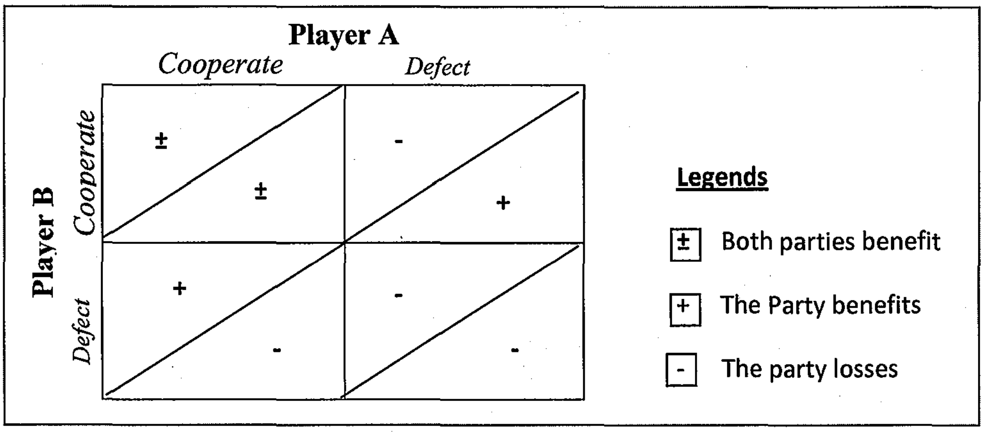

Figure II: Gaming logic for Pareto Optima model

Hawk-dove

Players in Hawk-dove game model always have implicit self intentions outside team's benefits during cooperation. Moreover, a part of players' motives in this gaming relationship model is to share the benefits of cooperation unequally. However, if cooperation succeeds between both parties, they are both worse-off. If the relationship fails, both parties benefit somewhat equally. Also, when both the relationship fails mid-way, the party that least co-operates benefits more in the long run, while the party that contributes more to the relationship looses more. Figure III illustrates hawk-dove gaming logic.

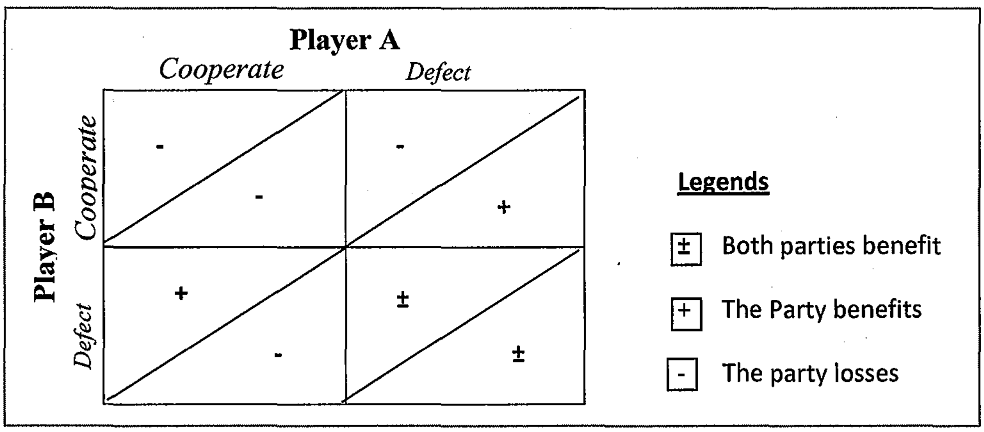

Figure III: Gaming logic for Hawk-dove model

DISCUSSION

Product development systems in construction are delimited by risks. These risks are not only stochastic; the industry currently has very limited options to definitively ameliorate all forms of risks. According to (Liu et al. 2003), construction has poor record in coping with risks and no part of construction stakeholders that has ever been vindicated by public concerns regarding the limitations of the industry. The industry therefore has few options; to develop and deploy workable tools that facilitate process improvement and restore public confidence or to endure predictable consequences of poor product performance. Having established the roles played by collaboration and system integration in servicing project performance through BIM, the adoption of its innovative platforms in this technology is still slow and fairly unimpressive. While some adherents of BIM drive the market through creation and dissemination of digital data, others have either not gotten a cue of how BIM works or how best to implement it. This could be linked to certain indices of industry peculiarity and complexity. However regardless of industry disincentives, many indications have shown that the BIM revolution has truly begun. (Aranda et al. 2008; Ballesty et al. 2007; Fusell et al. 2007; Khemlani 2007; Luciani 2008) have reported numerous case studies regarding this.

Game theory models described above can be used to predict possible outcomes under different collaboration scenarios. During perfect collaboration, all stakeholders cooperate to use tools that generate and standardized digital data within BIM integrated systems. In partial collaboration, some players do have the choice to maintain their old non-BIM compliant tools while rendering modern day professional services, while in null collaboration there is no framework for generating and managing data in forms that support process de-fragmentation - a challenge that has plagued the industry for centuries. In further interpreting gaming models in BIM, each stakeholder (also referred to as player) represents a node of information transmission and feedback between his point of action in BIM and the rest of the system. Considering prisoner's dilemma as a gaming lens in BIM philosophy, players do not have fully definitive powers to indemnify clients of all risks and uncertainties in project lifecycle. The model suggests that there are possibilities of outstanding benefits as much as players cooperate in collaboration. When all players adopt BIM, they are better-off - the least benefits being far more than what the best fragmented processes could offer. This has been established in (Aranda-Mena et al 2008a) in terms of cost, quality of service delivery and satisfaction of all parties involved. Even when each player is motivated by customized business drivers, the economic gains triggered in BIM collaborative platform are reasonable.

Pareto optima model suggests that all parties in cooperation (in integrated systems) benefit evenly. However, all the potentials of BIM will only be realized when it is not used as design tool alone, rather as a platform where all stakeholders are held in even esteem. (Peter and Dan 1999) have argued how tragic wanton egoism could impact on common course in integrated relationships. Arguably, one of the reasons why BIM seems to be making slow progress in the past years is that many non-design professionals who are predominant professional service providers in the industry see it as mainly a design tool with which they are reluctant to identify. There are misconceptions too that BIM threatens the relevance of these professionals. Gu et al

(2008) concluded that the rate of BIM adoption will only improve when other professional discover their roles in BIM and what is it in it for them. Even though designers benefit more in BIM at the moment, except other professionals are integrated into BIM initiatives, all parties will be worse-off in the long run. Hawk dove gaming model typifies fragmented processes because stakeholders perpetuate self-interest at the expense of objectivity and collaboration. Evidently, fragmented processes never helped product performance in the industry; hence the industry will be worse-off if parties perpetuate deliberate non-collaborative behaviours. However when individual parties adopt BIM, such party would enjoy the benefits of early entrant advantage in market competition. While the party that refuses to adopt BIM risks potential market relevance for competition and improvement in professional service delivery, such party also has a lot to loose in terms of survival and ability to keep up with the pace of future developments in the industry.

CONCLUSION

The challenges of fragmented processes in the industry have been underlined. Interestingly, better alternatives have been established in BIM potentials. Unlike manual and entity-based CAD, BIM provides platforms for stakeholders to collaborate, communicate, share data and values, and integrate intelligent technologies and techniques while driving digital design systems. However, the realization of BIM promises is still suffering some setbacks; adoption rate is slow, awareness level is not adequate, and there is marked weakness in market commitment and skill gaps in driving BIM realization. Three gaming models - prisoner's dilemma, pareto-optima and hawk-dove have been used to demonstrate possible implications of current developments in BIM adoption and associate challenges. It had been proved from these models that that best way to go is for the industry to device proactive strategies that will commit all stakeholders to participating in BIM adoption. This is because one of the industry's reliable chances of rebranding her image is for all parties to adopt BIM. Gradual and partial adoptions are fair, but will not guarantee sustainable solutions – not to adopt BIM will plunge the industry further into disrepute. Furthermore, in all cases of partial and no adoption, both the industry and her stakeholders (professionals and clients) are worse-off in the long run. The following recommendations are to further simplify the applicability of this study:

1. BIM technologies and allied behavioral concepts (philosophies of collaboration) should be integrated into academic and professional training programs at all levels in the industry.
2. More empirical studies should be focused on market drivers and incentives for BIM adoption in the industry.
3. Further research should be beamed into intra and inter-discipline implication of BIM adoption to generate improvment in adoption methodologies and discipline-specific limitations.

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