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BIM AND DESIGN AND CONSTRUCTION INTEGRATION – THE ROLE OF RELATIONSHIP MANAGEMENT AS THE CATALYST

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ABSTRACT
The extent to which relationship management enhances the rapidly developing disciplines of architectural technology and design management is the subject of this paper. The interface of people, technologies, policies and processes within a project environment is the main theme. How relationship management (RM) can improve project performance through the adoption (and adaptation) of collaborative communication technologies is also considered. These issues and the framework within which cooperative and collaborative design, moderated by BIM, is developing in Hong Kong are discussed with reference to two case studies. The cases show that the uptake of BIM is characterised by proactive and reactive approaches. BIM operates most effectively within a ‘no blame culture’ where no one loses ‘face’, an important cultural concept in Hong Kong.

1. INTRODUCTION
The construction industry lags behind other industries in adopting and integrating ICT. However, it is apparent that, at the level of both the firm and project team, there are indications that an increasing number of construction industry participants are moving beyond the mere automation of manual tasks. If construction projects are to be more effective, this will come as a consequence of greater integration of communications across the temporary project organization; that is the construction team. While the industry is still a long way from sector-wide performance improvements, there are enough ICT-mediated projects to make it possible to describe the attributes that a project and its participants require to create value at multiple levels across a project supply chain into which ICT has been integrated. Croker and Rowlinson (2007) recently pointed out that research on the adoption and use of ICT in the construction industry often fail to distinguish between permanent organizations and their project-based counterparts. They however confirm that in construction project settings the implementation of ICT is shaped generally by forces emanating from four contexts: external, internal, situational and organizational (Croker and Rowlinson, 2007).

Value creation by members of a temporary project organisation requires the involvement of the entire project supply chain including architect (ARC), mechanical, electrical and plant consultants and contractors (MEP) and main and trades contractors (STC) as shown in Figure 1. From the suppliers of raw materials upwards, inter-organisational business processes should be designed to facilitate the free exchange of information necessary for optimal flow of goods and services. Members of the supply chain who positively contribute to this process should expect to be rewarded through a combination of increased/repeat business and increased margins. Though the precise nature of the reward will vary from user to user and at different levels within the project supply chain, the concept should remain true throughout the project team. Such an integrated approach is built on the incremental capability improvements of individual project team members, who close the communication gap with other team members.

One such tool for closing the communication gaps among project participants is Building Information Modelling (BIM), a methodology for managing the essential building design and project data in digital format throughout the building’s life-cycle (Penttilä, 2006). Although BIM is a promising catalyst of change (Bernstein, 2005), with the potential to
reduce the industry’s fragmentation (Dawson, 2005) as well as lower the high cost due to inadequate interoperability (Gallaher et al., 2004), such a sea change in the culture of the industry cannot be brought about by technology alone: it is essential that processes and procedures are put in place on top of the procurement system in order to facilitate this change. Indeed, Succar (2009) recently made a case for the development of a framework that positions BIM as an integration of product and process modeling. The cooperation and collaboration which is shown schematically in Figure 1 depends to a great extent on the management of relationships within the temporary multi-organization which is the project team. Although this was recognised many years ago (Cherns and Bryant, 1984) the social infrastructure, relationship management (e.g. Rowlinson et al., 2006), and the technological infrastructure, visualization and BIM, were not well developed (Rowlinson and Yates, 2003). As these infrastructures now are starting to coalesce the opportunity for true cooperation is now beginning to emerge (Anvuur and Kumaraswamy, 2007).

Sustainability is also becoming an increasingly important issue when considering how a building will use resources over the course of its useful life. Government regulations, environmentally conscious construction clients, and the general public are driving demand for buildings with less reliance on external municipal services in addition to a reduced carbon footprint. BIM technology, when paired with ecological sustainable design (ESD) software, allows for extremely powerful models to be developed which accurately represent most aspects of sustainable design.

However, the uptake of BIM in construction projects is slow. The key to the adoption of BIM by major construction clients can be achieved by highlighting the benefits due to cost savings from less rework, increases in interoperability and accurate estimation of future facilities management (FM) costs by utilities consumption modelling. The BIM process requires a complete model before construction begins where clashes and other problems can be resolved virtually before encountered on site. Resistance to BIM will
occur in situations where architects and engineers, who traditionally expect the majority of the workload to be in the latter half of the design phase as RFIs are issued, have their workload shifted towards the beginning of the design phase. This undoubtedly requires a culture change and this may be achieved through relationship management. BIM reduces the workload later in the project by reducing the RFIs during project construction. This will likely modify the cash flow structure of these consultants and lead to additional management challenges. However, the benefits of this approach will outweigh the costs as total workload will be reduced over the project construction period. It is far faster and cheaper to modify a computer model than to modify a semi-constructed building. This will typically result in cost savings for architects and engineers as they can get things right first before construction starts and saving for the client as they have fewer disruptions due to RFI and cost overruns.

This paper makes a case for a relationship management approach to BIM implementation and illustrates how such an approach is evolving in the Hong Kong context. The BIM philosophy is first presented, followed by a review of how relationship management can facilitate BIM implementation. Two Hong Kong cases are then presented to illustrate the challenges and opportunities that a relationship management approach to BIM presents.

2. BIM PHILOSOPHY

As the development of new materials, construction techniques and technologies, and architectural ambitions increases the complexity of major construction projects, so too must the manner in which such projects are conceived and managed. Clients are beginning to move away from the traditional methods of project management with the desire to use modern technology effectively. The need to complete projects quickly and cost effectively and the competence to do this is what will continue to differentiate companies from one another. In the past, 3D technology had been used to create a conceptual visualization of a project, but failed to significantly change the traditional process of construction design and project management. The technology has been regarded as simply another form of demonstrative artwork with no real on-site application or practicality and no ethos of cooperation amongst team members to drive its use.

BIM has taken this concept to the next level by using actual engineering and architectural data to create the 3D models as opposed to creating the models directly with artistic 3D design software. This allows for a 3D model to be updated by way of changing the database containing the specifications and not the actual model itself. The model is simply an end result of the input data. Architects, structural engineers and other team members can then work independently using the same centralized dataset in a systematic, collaborative manner. The aim is to create a centralized shared knowledge resource that contains all the necessary design and operational information about a project. For example, as a structural engineer updates the model with new specifications, the architects will be automatically notified of the changes which can then be viewed in their own formats or as a 3D model. Traditionally, the structural engineers and the architects would work on separate sets of schematics which would need to be updated and coordinated as problems are identified, requiring a great deal of organisation and paperwork. The BIM approach also helps eliminate or reduce the need for graphic designers to update the model with data from professionals using vastly different design formats as the process is largely automated, being built into the functionality of the system.

BIM uses actual structural and architectural data that can be used to identify and reduce the number of errors and design conflicts and requests for information (RFIs) before the project ever breaks ground. Centralizing the dataset also has the benefit of maintaining a consistent format of data which reduces the confusion experienced by different specialists interpreting information. The resulting 3D model is not only a highly accurate
visual representation, but also a model that contains accurate structural, sustainability, energy use and other information. This allows for various project professionals to use the same data set to achieve different goals.

Recently, BIM has progressed beyond 3D visual representations to 4D representations of the entire construction process. This allows it to be an incredibly useful tool not only for participants in the design process, but those involved in the building process as well. For example, by simulating the build process, risky construction methods can be identified and designed out before it becomes too late and costly, with obvious occupational health and safety benefits. Costs can be reduced with the prefabrication of certain elements if the specifications are known well enough in advance, as this typically requires very long lead-times (say, up to 9 months). If requirements for materials are known far enough in advance, structural and architectural elements can be manufactured and delivered to the project using a just-on-time schedule to reduce the need for storage and delays.

3. BIM AND RELATIONSHIP MANAGEMENT

Major construction projects involve several key parties that require a great deal of direction in order to complete a project effectively. Firms need to continuously adapt and utilize new technologies, products, services and processes that can allow them to improve efficiency and remain competitive players in the market. Collaboration between key parties, such as architects and structural engineers, is critical in accomplishing this goal. The use of BIM technology is proving to be the facilitator of truly cooperative construction project management teams, allowing for a unified master dataset which all members of a project can use in the accomplishment of their specific tasks. While projects continue to increase in complexity and new construction materials continue to be developed, clients require projects to be completed in less time and more cost effectively than ever before. This is leading to modern technology being utilized in ways that facilitate an increase in the communication between traditionally segmented parties in the construction process. However, this is not automatic, the cooperation still has to be nurtured through relationship management techniques and facilitated through BIM. The need for a relationship management approach to BIM implementation is apparent from Succar’s (2009) view of BIM implementation as comprising three interrelated and mutually reinforcing fields that require management; the policy, process and technology fields. Here the policy field can be interpreted as aligned with the procurement arrangement or governance framework while Succar’s (2009) original process field is relabeled ‘players field’ and the process filed depicted as representing facilitative processes. These fields as shown in Figure 3 bring together a myriad of players or stakeholders and deliverables which then require effective management and coordination. While the emphasis has always been on the integration of the players, Succar’s (2009) adapted framework suggests that effective BIM implementation will require going beyond the players field to integrate the players with the technology, process and policy fields. This is because the new context in which BIM will operate effectively will be characterized by blurred roles, changes in responsibilities, shifts in potential liabilities and demands for new contract models and instruments of services (Bernstein, 2005). A relationship management approach should therefore help in resolving the tensions that will surround knotty issues such as efficiency, definition of roles, information value, innovation, business value, risks, contract models and sustainability of designs (c.f. Bernstein, 2005).

Since the demand for BIM is being driven by the potential for cost savings resulting from shorter project time horizons, less RFIs being issued on the project site which in turn results in fewer delays and cost overruns, the adoption and utilization of the BIM process will require top management support and ultimately need to be demanded by the client. In the past, consultants in the design and construction process had very little impact on the demand for BIM as they acted passively, subject to the requirements of the client. Through engagement, and empowerment, brought about by relationship management
techniques this situation is changing and effective design management is beginning to flourish, with the obvious advantages as shown in Figure 2.

Relationship management in construction has its roots in relationship marketing and strategic network competition (see, for example, Christopher et al. (2002) and Grönroos (1990)). Relational contracting is based on the concept that self-interest motivates parties to enter into contractual relations but competition between parties is necessarily bounded by acceptance of the need for cooperation (see, for example, MacNeil (1985, 2000)). Relational contracting provides a framework for cooperative and collaborative contractual relations; alliances and joint ventures are examples of this approach which can promote and engender innovation. Relationship management is the organizational behaviour which provides the infrastructure to stimulate and maintain collaborative relationships. Partnering is a policy or process to enable relationship management over a range of procurement forms which seeks to improve project performance. This is the glue which binds the project team, the temporary multi organization, together and provides the impetus for culture change and a move towards cooperative relationships.

In discussing their conceptual model of partnering and alliencing, Anvuur and Kumaraswamy (2007) note “several issues raise serious difficulties with ... partnering within and across different national and organizational settings”. To date, partnering has been implemented in Hong Kong as a process with little attention being paid to the impact of culture on the outcome of these processes: one size does not fit all and there is mounting evidence that partnering must be implemented in a culturally sensitive manner in order to be successful. Hence, culture, both organisational and national, affects the effectiveness of the partnering mechanism; a fit is required between the cultures and the mechanisms. Building on the work of Phua (2004) and Phua and Rowlinson (2004) on ingroup and outgroup cooperation Anvuur and Kumaraswamy (2007) propose a ‘contact hypothesis’ as a means of explaining how collaboration and cooperation can be brought about. They conclude that optimal collaboration requires “(1) equal status and respect (2) common goals (3) cooperative workgroup interaction (4) support from authority and egalitarian norms. As for industry change, a long term goal of the partnering process in Hong Kong is to change the culture of construction.

Implementing BIM with a relationship management philosophy in projects as discussed above can therefore lead to greater collaboration and cooperation. Succar (2009) makes this link more explicit in advocating the development of a BIM framework and espouses a BIM maturity continuum model that identifies a fixed starting point (i.e. pre-BIM, the status before BIM implementation), three fixed maturity stages and a variable ending point (i.e. integrated project delivery denoting an approach to or an ultimate goal of implementing BIM that accounts for unforeseen future advancement in technology). Through the integration of the technology, process, players and policy fields, Succar (2009) outlines the three stages of BIM maturity as: object-based modelling, model-based collaboration and network-based integration which are indicative of increasing need for forging better relationships among stakeholders.

From a relationship management perspective, the pre-BIM stage requires that collaborative practices among stakeholders be made a priority with the removal of linear and asynchronous workflow between the stakeholders. The realization of the need to invest in technology and promote interoperability is often evident at this stage (Dawson, 2005, Gallaher et al., 2004).
At the object-based modelling phase when BIM is initiated, collaborative practices are often limited as there are no significant model-based interchanges between different disciplines, data exchanges are also still unidirectional and communication is also asynchronous and disjointed (Succar, 2009). However, as BIM begins to bring up design and construction issues that require resolution the need to engage key stakeholders becomes apparent. This way, the object-based phase evolves into the model-based collaboration phase where stakeholders engage in interoperable exchanges. At this stage, model-based interchanges begin to augment and replace document-based workflows resulting in ‘fast-tracking’ of the project and greater need for collaboration and cooperation (Succar, 2009). When the BIM implementation reaches the network-based integration maturity stage, a more interdisciplinary approach to developing models for managing the construction process would have evolved where more complex analyses of the early stages of virtual design and construction is undertaken, going
beyond semantic object properties to include business intelligence, lean construction principles, sustainable policies and whole lifecycle costing (Succar, 2009). Due to the demands for collaboration at this stage rethinking of contractual relationships, risk allocation models and procedural flows are necessary. The management of these changes and the resulting tensions can be facilitated by an application of the principles of relationship management. This should then push the implementation of BIM towards an integrated project delivery phase with innovative procurement systems as the ultimate desired end.

Although Bresnen and Marshall (2000) and Fisher and Green (2001) question whether relationship management principles such as partnering can change the culture of construction, the results which are flowing from BIM moderated projects suggest that, in Hong Kong at least, this may be possible. A key issue here is that the BIM model does not lay blame; it merely identifies clashes, issues or problems which can be solved participatively. In essence, no one loses ‘face’, which is an important cultural concept in Hong Kong. The success of partnering is mediated by the influence of culture, procurement systems and the process of relationship management. Thus, this paper builds on the work on the impact of culture on project performance (see, for example, Rowlinson et al. (in press)) to outline the efficacy of the relationship management approach and how innovation, in the form of collaborative working through 3D and 4D visualization and BIM, can lead to collaboration and cooperation. The case studies below illustrate these points.

4. CASE STUDIES

The adoption of BIM processes on Hong Kong projects has evolved in an ad-hoc manner to date with a number of different parties providing BIM services and software solutions. The Hong Kong construction industry has been influenced by developments in the United States and Europe in the past five years. A number of large client organizations specify that their design consultants and contractors must adopt BIM technologies for their projects. In one such case, the client invested directly in the implementation, training, and management of the BIM technology. In contrast, other developers only specify BIM and allow the consultants to offer suitable BIM solutions for each project. In these cases the architects, engineers and contractors have engaged independent BIM consultants to assist in the planning and management of the BIM processes.

Larger design consultancy firms have also invested in developing BIM solutions within their respective firms. The goal has been to improve design co-ordination and drawing production efficiency on specific projects. Although the companies do not appear to have a corporate directive to make BIM software tools mandatory on all of their projects, they have made the technology accessible to all of their staff. As observed in Europe and the United States, management contractors have been the fastest adopters of these collaborative tools. These firms use BIM and 3D CAD solutions to improve building services co-ordination. They use 4D virtual construction simulations (3D models digitally linked to a programme) to review construction sequences and to communicate planned tasks to the sub-contractors and local authorities. Recently, representatives from client organizations, developers, design consultants, BIM consultants and contractors founded the Hong Kong Institute of Building Information Modeling (HKIBIM). The objectives of the HKIBIM are to promote and advance the education, understanding, appreciation and interest in BIM in Hong Kong. The Institute will enable the different parties involved in building projects to develop strategies for a project and provide and maintain standards for BIM practice locally.

Against this backdrop two projects that have recently adopted BIM are discussed to demonstrate the proactive (4.1) and reactive (4.2) approaches to BIM process implementation in Hong Kong so far.
4.1 Case Study One – Cargo Terminal

Located on the south side of the Hong Kong International Airport platform this cargo terminal facility, costing roughly USD$500M, is possibly the largest project in Asia to implement BIM technology. The facility will be the largest air cargo terminal in the world (when measured by tonnage per square metre) with a target throughput capacity of 2.6 million tonnes of cargo per annum. At peak times, the cargo terminal will process more than 75 flights per day with each flight containing up to 110 tonnes of cargo from silver bullets (converted 747 cargo carriers) or up to 25 tonnes from passenger planes.

The client specified that the design must be coordinated using the BIM process from the very beginning of the design stages. The client was determined to use the latest technology available to reduce the risk of delays and cost over-runs on the complex fast-track building. The cargo facility is a structure with a very specific purpose that requires extensive mechanical, drainage, ventilation, electrical, and specialised mechanical systems. As the design, drawings and specifications for these systems are incorporated into the BIM, a detailed clash detection analysis matrix can be implemented to identify and eliminate any design conflicts between various systems (cargo handling, structural, architectural, municipal systems, specialised systems).

![Figure 3. Schematic showing the complexity of the new CX cargo terminal.](image)

There are different types of clashes that must be indentified in a project such as this. A hard clash will exist where piping or other systems are passing through or otherwise interfering with structural or architectural elements. This could cause a delay on site that might require an RFI if overlooked during the design process. Cargo enters the facility on 6 tonne pallets which are then processed by the Materials Handling System (MHS). The MHS consists of a semi-automated assembly of roller-decks, which move the cargo pallets laterally while large hoists are used to raise or lower the pallets vertically between levels. This requires the BIM to account for the different systems that may have
a clearance clash with the 'kinetic envelope’ of the cargo pallets as they are moved and process throughout the facility.

Clashes can be identified using a specialized clash matrix that incorporates design specifications and operational requirements (headroom, mechanical handling system (MHS) specifications, structural and architectural co-ordination, and mechanical, electrical and plant (MEP) co-ordination) into the analysis. The analysis is done on a priority basis and issues are resolved before any construction ever begins. This is a continual process and a dedicated engineer works on this continuously through-out the design co-ordination process. This has resulted in far less on-site requests for information (RFIs), cost over-runs, and delays. It is difficult to imagine this project being successfully completed in the given time-frame without using BIM process management.

The proactive approach adopted by the client in this project has resulted in smoother operation and forced traditionally segregated elements of the design process (structural engineers, architects, MEP, etc) to collaborate in a systematic fashion from the outset. This has required the extensive retraining of key personnel to use standardized systems and software platforms to ensure that there is consistency in the design and format of data. As one might imagine, there has been significant resistance to the change in process, but the resulting outcome benefits all parties involved in the construction design and build process. Indeed, the approach appears to be bringing about the intended culture change in the industry.

“We believe that 3D design is an essential tool for a project such as ours. Its introduction has required a commitment from designers and contractors and at times we have had to insist that sliding back to 2D methods is just not acceptable. Now all parties are able to see the benefits of BIM and I believe that for most of us there is no going back.” [Client’s Project Director]

4.2 Case Study Two – Casino (Parcel 5 & 6)

The construction of the Casino was managed a management contractor. During Phase One of the development, there were a number of complex design co-ordination issues between the architectural glass reinforced concrete (GRC) façade panels and the in-situ structural concrete frame. The issues were causing delays on site while RFIs were issued to the engineering and architectural consultants for resolution. In reaction to the challenges on phase one, the client supported the adoption of BIM 3D CAD modeling during the detailed design phase and construction documentation stage before the specialised façade contractor was appointed. A 3D modeling consultant was appointed to work in parallel to the architects and structural engineers to build 3D CAD models to identify design conflicts where structural elements were clashing with architectural elements of the façade. These issues were then resolved by the designers before the drawings were issued to the contractors. The design for the development of Parcel 5and6 involves a podium façade with a design reflecting Balinese styles. The 250m long elevation consists of 18 different themed facades which are all inter-connected. The facades are constructed using GRC precast panels which are supported by a cast in place reinforced concrete frame structure. During the design, tender and construction of the first phase of the Casino, there were a number of design integration problems between the Casino’s themed GRC facades and the concrete structures. The design issues contributed to delays during the tender and construction stages.
At the commencement of the 12 week detailed design and tender documentation phase for the Parcel 5 & 6 Façade project, the management contractor appointed a 3D modeling consultant to provide 3D CAD models assembled from the architects and structural engineers 2D CAD drawings. The 3D modeling consultant’s co-ordination engineers were instructed to identify design clashes, conflicting information and missing details on the consultant’s drawings. A schedule of work was developed with the design team to integrate the 3D CAD design validation review into the overall design co-ordination process. The 3D structural modelling team assembled the structural frame model from the designer’s 2D CAD drawings. The 3D architectural modelling team built the GRC façade models from the architect’s 2D CAD drawings.

As the design for each of the 18 themed facades was completed, a report was compiled by 3D modeling consultant identifying issues which required the attention of the architects and engineers. These issues included conflicting information between architectural plans, sections and elevations, misalignment and setting out issues between the structural framing and GRC panels and many other technical queries. These issues were previously discovered by the main contractor on site.

The architect and structural engineers issued drawings to the 3D modelling team on a weekly basis. One week later a design co-ordination workshop was facilitated by the management contractor to review the design progress and to resolve the technical queries raised from the 3D modelling process. The 3D models were used throughout the design co-ordination process to review details and to illustrate different design conditions. The 3D models became the focal point for discussions between the client, architect and engineers. The architects and engineers made design changes and revised their respective 2D drawings according to decisions made during the co-ordination workshops. The updated drawings were then incorporated in the 3D CAD models to ensure that the issues raised previously were fully resolved.

There was an initial resistance from the architects and engineers to the inclusion of an independent check by the 3D CAD modelling team. However, after they witnessed the benefits of the models and technical query process, they were able to quickly understand co-ordination issues illustrated by the 3D models. The designers quickly became fully engaged in the process. At the end of the scheduled 12 week tender documentation process, the architects and engineers produced a set of fully co-ordinated design.
5. CONCLUSIONS

Business success alone is insufficient as a driver for managers to justify the implementation of integrated ICT strategies, unless there is strong support for such change from ICT champions (preferably senior management within the organisation). Indeed, being motivated only by profit maximisation (or other desirable financial objectives) is not enough. Many firms adopt ICT tools and systems for profit-motivated reasons and fail due to underestimation of cost, i.e. successful ICT adoption depends on the ‘politics of technology’ in its management in the organisation (Tantoush et al., 2001) and shaped generally by forces emanating from external, internal, situational and organizational contexts (Croker and Rowlinson, 2007).

A change of culture is necessary and the implementation of BIM in project delivery must be accompanied by a relationship management approach and a move towards more integrated procurement systems, such as alliances and design build approaches. With such prerequisites in mind, the feasibility and decision-making process of implementing a change/new ICT system within an existing organisation can be made easier by maintaining openness and honesty throughout the planning, design, development and implementation process. A relationship management approach can encourage participatory planning in defining goals, objectives and in influencing the design or procurement of the new ICT system in ways the enable the smooth integration of the technology, project processes and policies.

Managerial support, involvement and commitment are therefore necessary in driving the changes necessary from the beginning to the end of the planning and implementation process. A clear management vision for the implementation of BIM will also enable clear articulation of the goals for the change so that they are better understood and viewed positively by all concerned. Overall benefits from BIM implementation can be maximised if greater effort is placed on coordinating the goals of the new system with the existing goals of the organisation. As resistance to change often arises from lack of adequate knowledge or information and inexperience, there must be enough opportunities for education and training on using the new system as well as positive incentives for it.

As the Hong Kong cases show, resistance to change will often characterise the uptake of BIM. Thus, the process will continue to be driven by both reactive and proactive approaches until such a time that clear benefits to all stakeholders in the construction process can be demonstrated. However, relationship management will continue to be a key ingredient in the successful integration of the stakeholders for success in the application of BIM.

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7. REFERENCES


