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The contemporaneous use of building information modeling and relational project delivery arrangements

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Abstract

The initiatives of building information modelling (BIM) and relational project delivery arrangements (RPDA) have traditionally been quite different, although both aim to enhance customer value. BIM was developed to serve as an information center and collaboration and simulation model, whereas RPDA's were developed to foster a search for a mutual and single project objective through early stakeholder involvement and integration. However, recent experiences have indicated some reasons for suspecting that BIM and RPDA, surprisingly, have a lot in common. This paper studies the contemporaneous use of BIM and RPDA and aims at finding out the main benefits when utilized simultaneously.

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Keywords: BIM, RPDA, Construction, project delivery methods, Alliance, IPD, Collaboration model, design quality, construction quality, simulation, 4D Model.

1. Introduction

Several studies assess the low productivity development of the construction industry (Allmon et al. 2000, Rojas and Aramvareekul 2003, Abdel-Wahab et al. 2008). Increase in output has been mainly buried in many countries under cost increases in input (Pekuri et al. 2011). On one hand, the former occurs because of the fragmentation of project deployment, but the stakeholders' actions with their multiple interests in a project also partially affect output.

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Each stakeholder has specific requirements with respect to a project that can create fundamental conflicts with others (e.g., many functions versus a low budget and no overruns) (Aapaoja and Haapasalo 2014). Despite the complexity of projects, requirements and schedules have been continuously tightening, according to Brady (2011). This increases the challenges for the integration and management of the project team members because more interactive collaboration between them is needed. Traditional methods (e.g., design-bid-build, D-B-B) have mainly been based on bilateral contracts and the lowest bid, which does not encourage collaboration because the project stakeholders try to optimize their own operations and risks. The challenges highlight the problems of the traditional methods and have forced the industry to seek other methods to establish better collaboration, such as relational project delivery arrangements (RPDA), as discussed by Davies et al. (2007), Brady et al. (2006) and Aapaoja et al. (2013).

Building information modelling (BIM) has been forecasted to solve several problems. BIM has been seen as an integrator of fragmented stakeholders, correcting the problems in information and data flow, improving quality, speeding up the process and so on (Aschcraft 2008, BIM Handbook 2008, Succar 2009). However, BIM has not been able to deliver all its promises – so far. This might be the reason for unrealistic expectations in terms of technology solely solving hidden problems. The rate of utilizing BIM has also dragged behind the possibilities (Haapasalo 2000). It seems that BIM professionals will have to push the industry to adopt higher utilisation rates to realize the benefits. BIM and RPDA seem to have mutual goals. RPDA’s benefit is that it integrates the stakeholders in the project to work for the best of the whole project. Project alliancing and integrated project delivery (IPD) are RPDA types of project delivery methods. It is evident that very significant changes need to take place to increase productivity in the construction industry and to renew the cultural and operational logic. Our aim is to study whether the aforementioned problems in fragmentation and information can be solved through integration of stakeholders using BIM as a tool (Figure 1). We have condensed this into the following research questions:

- RQ1. What are the characteristics of BIM?
- RQ2. What are the characteristics of RPDA?
- RQ3. What are the benefits of contemporaneous use of RPDA and BIM?

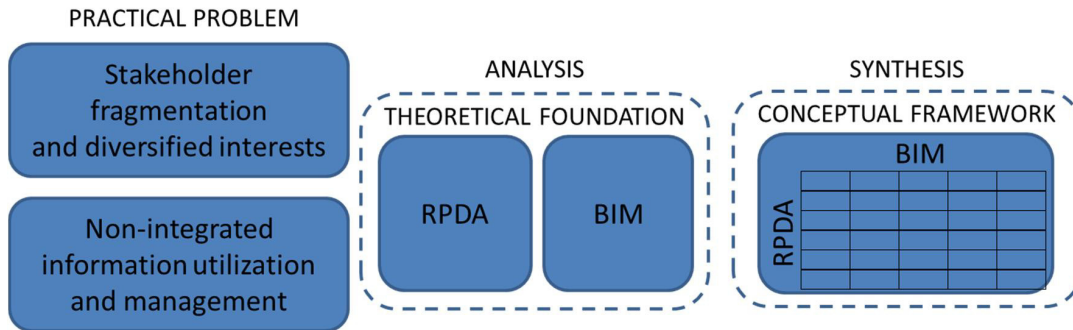


Figure 1. The conceptual in nature as logic of the paper.

2. Characteristics of RPDA

The literature dealing with general management recognizes two main phases in a project’s life cycle, the design phase and implementation phase. RPDA, such as project alliancing and IPD, have been around for a while now. During the past decade, there has been more effort to bridge the existing gap between the design and implementation phases of construction projects, since the traditional delivery methods (e.g., design-bid-build) have been shown to be insufficiently efficient, as discussed by Lahdenperä (2012).

A construction project is, generally, a system comprising multiple stakeholders having interrelationships amongst themselves and the environment, and a project's primary mission, after all, fulfils the needs and requirements of the end customer. In addition, the project should ensure the well-being and emergence of the other stakeholders at the same time. However, this has been a major problem in construction projects carried out through traditional methods. That is exactly the issue that the RPDAs aim to optimize; hence, it has some distinctive characteristics that separate it from traditional delivery methods.

RPDA aims to combine project processes and working practices of the stakeholders in order to deliver and optimize an entire project, not pieces, as effectively as possible by contrasting the customers' purpose and what they want against the means (how it is done) and constraints (e.g., budget, regulations and time) presented by the stakeholders. In other words, it means that a project should have a mutual and single objective to which all the stakeholders are committed. However, in order to form the best possible mutual objective, it demands that the project stakeholders are involved as early as possible and that they work as an integrated team. Team integration brings together various skills and knowledge that improve the effective and efficient delivery of the project, while early stakeholder involvement maximizes the benefit received from the stakeholders' capabilities and hence prevents unnecessary iterations and changes of project plans. If the characteristics of RPDA (Table 1) are considered, all these factors can be placed under these aforementioned elements (i.e., Integration, mutual and single objective, and early involvement of key stakeholders).

Table 1: The characteristics of RPDA.

Key element	Characteristics	Aim	Literature source
Mutual and single object	Mutual and single project objective	Comprehensive optimization of the results, instead of sub-optimization. 'We win or lose together.'	Lahdenperä (2012), Hoezen (2012)
	Open accounting documents among team members	The game must be open and honest if the results and risks are to be shared.	Ross (2003), Cohen (2010)
	Shared project benefits and risks (value-based approach)	Benefits and risks are collectively managed and appropriately managed. All decisions are made 'best for the project.'	Lahdenperä (2012), Dainty et al. (2001), Walker and Lloyd-Walker (2014)
	Unrestrained communication and wide use of technology	Digitally based and virtual (e.g., BIM)	Hoezen 2012, Bromley et al. (2003)
Integration	No organizational boundaries	Solid team spirit that contributes to the outcomes	SFC (2003)
	Co-location of a project team	Enhances the communication and interaction among team (tacit knowledge).	SFC (2003), Bromley et al. (2003)
	Focus on solving problems, not on finding out who is guilty ('no blame' culture)	Blaming doesn't benefit value creation, thus the focus must be to make sure those mistakes don't happen again.	Dainty et al. (2001), Ross (2003)
	Fair and respectful culture among team members	Collective responsibility for project performance encourages innovative thinking.	Dainty et al. (2001), Lahdenpera (2012), Hoezen (2012)
	Value co-creation	Value co-creation shifts the mindset from a traditional 'subsystem delivery' to 'system ensemble and experience co-creation'.	Ramaswamy and Gouillart (2010), Walker and Lloyd-Walker (2014)
Early stakeholder involvement	Early involvement of key stakeholder	Early and effective contribution of the core competencies and knowledge	Aapaoja et al. (2013), Kent and Becerik-Gerber (2010)
	Each team member has an equal opportunity to contribute to the project objective and delivery process.	Concurrent and multi-level contribution and knowledge sharing over the inter-organizational boundaries	Bromley et al. (2003), Lahdenpera (2012)

Increased predictability of overall costs and schedule	More reliable and finished plans through collaboration. Continuous review of schedule through interaction and collaboration.	Baiden et al. (2003), Anumba et al. (2002), Mossmann et al. (2010)
Unrestrained communication and wide use of technology	Digitally based and virtual (e.g., BIM)	Hoezen 2012, Bromley et al. (2003)

3. Characteristics of BIM

Building information modelling can be used to create an information centre for a project's lifetime. Collaboration models improve the quality of design and construction. They also improve the communication and cooperation between stakeholders. Simulations made using the BIM help to plan constructability, operations and maintenance.

BIM has been developed to act as the centre for project information. The use of BIM started from as a functionality tool for designers to handle the integrity of design work. With the development of information and communication technologies (ICT), we have been able to develop the role of BIM to be the information centre for all project phases. When we change the model, we are able to output new versions of the drawings where the information is correct. In addition using the model, we are able to produce 3D visualization drawings, virtual reality models and 4D-simulations, and we can actually simulate different attributes of a facility, such as costs, energy consumption, traffic, traffic lights and traffic guidance. User/maintenance manuals can be linked to the model as pdf files. These document tags are then easy to find (visually) in the virtual reality model, or they can be searched using the metadata information attached to the document. BIM acts as the information centre for all the stakeholders. Designers are able to see other design sub-domains work as the collaboration model is updated. Information is also available for constructors, who are able to use the information for automated machinery during construction work. As build data can be collected during the construction process and is the essential base for operation and maintenance systems. BIM can serve as information centre for a project during its lifetime.

Collaboration models merged from different domains' sub-models help to improve the quality of design, and they decrease the cost in construction and help to improve the construction process, as discussed by Azhar (2008) and Eastman et al. (2011). Earlier research, such as Eastman et al. (2011), has shown that collaboration models with clash detection application can help to find almost all the design mistakes before the construction phase begins. According to Azhar (2008), design mistakes represent 40% of all issues that cause breaks in construction work. The use of collaboration models can reduce cost significantly by lowering the number of change orders and extra work in construction. Project timelines are also shorter. This decreases waste in construction and lowers the usage of energy and materials; in other words, as noted by Estman et al. (2011) Sacks et al. (2009) and Aschcraft (2008), it makes the construction process more sustainable.

Common real-time collaboration model helps improve communication between stakeholders (Eastman et al. 2011). Collaboration models spread the information about a project, and all stakeholders are able to see and understand other stakeholders' aims and how other designers' work influences their own work. It is essential that constructors and maintenance experts see the design in an understandable format and that they are able to comment and influence the design work. Collaboration models also serve as communication centres because comments can be added to the model so that they are visible for all. Comments can be stored and filed in the model so that they are readable during the later phases of project. One common model makes the early involvement of all stakeholders easier.

Simulations made using BIM information help to plan constructability, operations and maintenance. Simulations are useful to all stakeholders when all are striving towards the best added value for a customer. When we combine the schedule with a 3D model of the project, we can talk about a 4D model, where time is the 4th dimension, according to Eastman et al. (2011). With these kinds of simulations based on a real planned schedule of a project, it is possible to plan and improve the construction process. Models may also include additional information. It is popular to talk about 5D, 6D or 7D models when we add attributes such as costs, energy consumption, resources or CO2 emission formulas to a model. The model which was made first to help the designer is now developed to be an

important tool for the whole project for estimating not only the technical quality of design and construction but also what kind of environmental, usability, maintenance and operational effects and consequences the project has. Models and simulations can be very informative. With 3D user interfaces like Oculus headsets and cave environments, end users and designers are able to test how successful the design is on a 1:1 scale. These kinds of systems can be used to train operation personnel before the construction is finished. It is also cheaper to train employees in virtual environments than in real-life facilities. Artificial environments are useful also in “Big Room” set-ups. They can give added value to employees working in a Big Room, or they can even replace the actual Big Room with a virtual Big Room. During the design and construction process, all relevant information can be stored to the model. This information helps the commissioning and the handover of the facility to the client. An as-built model can be moved further on to facility management systems and can be used to simulate the operation phase and verify that all structures, guiding systems and equipment work properly before the facility is put in use. The use of model-based simulations can help to develop a better construction process, reduce operation and maintenance costs, and facilitate safe operations and more efficient maintenance, as discussed in Wong and Fan (2013) and Eastman et al. (2011). The various characteristics of BIM are listed in Table 2.

Table 2: The characteristics of BIM.

Key element	Characteristics	Aim
Information centre	All information is stored into the model or the model has direct links to the information.	Model works as common information source and information storage for stakeholders. Enables the reuse of data through the project lifetime.
Collaboration model	A collaboration model can be used to find clashes between design domains and to find other design mistakes.	The quality of design gets better, with less waste, more sustainable construction, shorter timelines and less construction costs.
	A common real-time collaboration model helps improve communication between stakeholders.	Model can be used as a basis for communication and documentation. A continuously updated collaboration model shows the real design situation to all stakeholders. They have common knowledge of design.
	BIM helps to arrange collaborative meetings based on a shared model and a virtual reality application.	All designers can follow the whole project’s situation from one common collaboration model. One common model makes the early involvement of all stakeholders easier.
Simulations	Model can be used to simulate the construction operation and maintenance process.	Better construction process. Less operation and maintenance costs, more safe operation, more efficient maintenance, less energy consumption.

4. The contemporaneous use of BIM and RPDA

The biggest challenges in project delivery are fragmentation and conflicts among multiple stakeholders’ interests during a project. RPDA projects characteristically include activities that are integrated, with a mutual and single project objective and early involvement and with common pain-and-gain terms that prevent fragmentation. RPDA projects are intended to bridge the gap between designers and constructors. The ultimate goal is to increase the added value that the customer receives. BIM is a technology which has features that affect the project procedures. The characteristics of BIM can be classified into three groups. BIM can serve as an information centre for all stakeholders in the project. Data is stored only once in a database. Collaboration models are composed from different design domain sub-models to improve the quality of designs. They help improve communication and the documentation of communication between stakeholders. Collaboration models help all stakeholders to understand the current overall design situation in a Big Room. Simulations help to plan constructability, operation and maintenance.

In RPDA projects, there is single and a mutual project objective. Project benefits and risks are shared. They are collectively and appropriately managed, and decisions are made that are 'best for the project'. Each stakeholder has an equal opportunity to contribute to the project objective and to the delivery process, starting from the feasibility study to commissioning and operation. This is in good harmony with the tools that BIM can provide for project members. BIM has all the needed information for the project and project parties. Collaboration models utilize 3D applications to show and combine all sub-designs to the same model. This gives equal opportunity for all stakeholders to estimate how current designs affect their part of the project. Collaboration models provide all the information equally for all the stakeholders and enable different kinds of analyses to prevent problems; if they happen, BIM helps to find better solutions. Simulations of the whole project model can be used to guarantee that the decisions made are appropriate for the mutual and single project objective.

It is characteristic to RPDA type projects that the activities are integrated. BIM supports this characteristic feature very well. All information is available to all stakeholders in the same model. Virtual reality models and simulations help all stakeholders to understand and influence each other's work. BIM supports the integration in projects, and vice versa, all information in BIM is available for all stakeholders without any additional agreements. Value co-creation adds the perspective of project stakeholder collaboration into the concept of value creation, and it shifts the mindset from a traditional 'subsystem delivery' to 'system ensemble and experience co-creation'. There are no organizational boundaries, so each project member has the opportunity and motivation to use the information to contribute to the best of the whole project. Big Room is a solution to take care of co-location. Project staff can work in the same premises for the period of project. Collaboration models make the co-operation easier in Big Room. All stakeholders have the same easy-to-understand view of a current project situation. There is a focus on solving problems, not on finding out who is guilty. This kind of 'no blame' culture releases all parties to think about how to solve all challenges for the best interests of the whole project. Blaming doesn't benefit value creation, thus the focus must be to make sure that mistakes don't happen again. A model helps to find the root cause of the problem and then simulate and test corrections. BIM is a good tool for value co-creation. It is possible to make costs, energy consumption, resources or CO2 emission simulations with the model and ensure that the solution brings the maximum added value to the customer. Early involvement of key stakeholders is essential. Early and effective contributions of the core competencies and knowledge even from the start of the project guarantee that necessary changes in the project are possible to make. According to the MacLeamy curve, the ability to impact cost and functional capabilities is highest in the beginning of a project. The cost of design change gets higher towards the end of the project, so it is preferable that the design process is already active in the beginning of the project. Traditionally, design is done close to the construction phase, when the cost of change is bigger and the ability to make changes is smaller. Both RPDA and the use of BIM have the same effects. Light (2014) confirms that the design phase should be moved to an earlier phase in a project's timeline. Both BIM and RPDA help in terms of earlier collaboration. With collaboration models it is possible to virtually construct a facility and ensure that there are no clashes or other design mistakes. Early involvement is one of the key elements in RPDA projects. BIM, as a form of a collaboration model, provides good opportunities to achieve early involvement. It is possible to make draft model of a project already in the feasibility stage. Models enable cost estimates if the models are linked to the proper cost database. 3D simulations that include cost information help to push the design towards the target value of a project. Constructability can be estimated with the help of 4D simulation. In 4D simulation, the schedule of the project is combined with the model. Collaboration models with clash detection software help to find clashes between different design domains. An entire project's life phases, from feasibility study, planning, detailed design, construction, operation and maintenance, can be simulated in the early stage of the project. This decreases the risks in the project and helps all stakeholders to check that their actions are in the best interests of the project early in the project timeline. Simulation of an operation is valuable to all stakeholders because it makes it possible to estimate the challenges during the operation as well as what kind of obstacles there might be for maintenance work.

5. Discussion and conclusions

The key features of BIM are comprehensive data storage, collaboration models and simulation. The key features of RPDA are integration, a mutual and single project objective, early involvement and communication. The contemporaneous use of BIM and RPDA give benefits to the project. This is in line with the Sachs et al. (2009) paper, in which the interaction of lean principles and BIM functionalities were studied. It has been noted that the use of BIM and RPDA both change the timing of design earlier in the project timeline. BIM is a technology that enables early communication between designers and constructors. In RPDA project agreements, the early involvement of all stakeholders is the key characteristic. BIM is a technology that eases early involvement.

The contemporaneous use of RPDA and BIM are mandatory in an integrated form of agreement (IFOA), as outlined by the AIA Document C191 (2009). This is not the case in general alliance agreements. The benefits of BIM have been brought up in many research studies. This paper confirms, especially in RPDA projects, that the use of BIM helps to reach RPDA goals. A practical implementation suggestion is to use collaboration models in Big Rooms to help improve the communication between all stakeholders. A virtual reality view of a real design situation is informative to all stakeholders as well as to non-professionals. The project data is unambiguously in one place in one form to be edited and viewed with different applications in an office or on site by all stakeholders. A collaboration model can be used to find clashes and other design defects. Simulations with 4D models help to plan a production process and to evaluate the fluency of operations and maintenance. The use of BIM in RPDA projects is useful to all stakeholders in terms of how it generates more added value to the client. Design quality gets better, construction is more efficient and sustainable, and operations are smoother and defect free. Maintenance can also be based on an as-built model. Clients should require the contemporaneous use of RPDA and BIM more often.

This study examined the characteristic features of RPDA and BIM and then investigated how they give more benefits than used alone. We found three main categories of RPDA characteristics. Integration is easier with a common model that includes the necessary information for all stakeholders during all project phases. BIM helps to strive towards a single and mutual project objective. Collaboration models bring the information equally to all stakeholders in an easy-to-understand form. Various simulations enabled by BIM help to ensure that all design decisions help to bring more added value to the customer. Early involvement is an essential feature of both RPDA and BIM. They both cause the same effects, and together they ensure that design decisions are made easily and when they are easy to make, and they keep the cost of changes low. This study is conceptual in nature and makes conclusions based on the literature and writer's 30 years of experience in infrastructure projects and 18 years of experience in BIM implementation. However, there is a risk that all these benefits of contemporaneous use of RPDA and BIM do not always happen. In practice, many of the projects are still delivered using traditional DBB project delivery methods. It would be useful to study how BIM technology and some lean principles could be utilized in more traditional type projects.

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