BUSINESS INTEROPERABILITY IN THE CONTEXT OF BIM-BASED PROJECTS

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ABSTRACT

This paper proposes a model that closely captures the factors that are responsible for Business Interoperability in the context of collaborative business processes for the deployment of Building Information Modeling. The Business Interoperability Quotient Measurement Model (BIQMM), uses an interdisciplinary approach to capture the key elements responsible for collaboration performance and BIM platform configuration. Through the quantification of the relevance of each element to the particular collaboration scenario, and with the combination of the BIQMM with a multi-criteria decision making tool, the Analytical Network Process (ANP) approach, this model enables a quantitative analysis of Business Interoperability for BIM-based projects, so that an overall interoperability score can be calculated for enhanced performance measurements. An application scenario is presented and the application of the BIQMM and ANP, provides a comprehensive framework for interoperability measurement. The paper concludes by recognizing that relationships between business interoperability and true AEC performance improvements and subsequent economic benefits derived from BIM-based approaches needs to be further developed.

Keywords: Business Interoperability, BIM, Collaborative Working Environments

1. INTRODUCTION

The use of BIM as a central repository for the building project information is promising and can revolutionize information management for a project and throughout its life-cycle. The model may enable better access to project information, and thus improve project understanding and control, and thereby become a powerful management tool. Within a project, BIM can be developed from a top-down perspective, that is, with the owner demanding the exact tools to be deployed by the project consortium, although this approach is unlikely to be sustainable if the owners wish that a market exists. Conversely, the BIM model can be developed using heterogeneous software tools that are interoperable with each other, which allows for a large disparity of software tools and vendors to co-exist and make markets more efficient. There is an overall consensus about the need for the BIM approach to be sustained in interoperability amongst software tools. The interoperability dimension is critical for the success of BIM, as within a project there are many different interactions between the various participants across the building project throughout the whole life-cycle, i.e., from the inception phase until demolition. The actual perspective of interoperability advocates that this problem is not just an ICT issue, which is to say that it is not just about connecting information systems but these other dimensions have been only partially addressed by the BIM community.

This paper describes the development of a model that closely captures the factors that are responsible for Business Interoperability for Collaborative Business Processes in the context of the AEC sector, particularly where BIM approaches are implemented. The Business Interoperability Quotient Measurement Model (BIQMM), uses an interdisciplinary approach to capture the key elements responsible for collaboration performance, critical in any BIM-based project. Through the quantification of the relevance of each element to the particular BIM collaboration scenario, and with the combination of the BIQMM with the Analytical Network Process (ANP) approach, the model enables a quantitative analysis of Business Interoperability, so that an overall interoperability score can be arrived at for enhanced performance measurements on BIM-based projects. A case study is presented to validate the theoretical model. The paper demonstrates that a comprehensive approach to assessing business interoperability is not only necessary but also feasible, and only an interdisciplinary approach can be a true benchmark of business collaboration performances in the context of BIM implementations.

2. BIM-BASED PROJECTS

Building Information Modeling (BIM) allows the visualization and understanding of construction projects to take place in 3D dimensions. BIM has benefited from the advent of sophisticated CAD systems, where it is possible to enrich the 3D models of buildings and structures with, in addition to vectorial data, complementary data such as physical characteristics, unit costs, quantity take-offs, etc. (see e.g. Kymmel, (2008) and National Building Information Modeling Standard, (2007)). Model intelligence refers to the fact that information may be contained in a virtual 3D model. Some of this information is physical, as it will contain information about the nature of an object, such as dimensions of the object, its location in relation to other objects in the model, the quantity of objects in the model, and other parametric information about the object.

Various models of different components of a BIM-based project can be collected into a composed model that will have the combined information from all the sub-models embedded in it. The architectural, structural, and HVAC models that are often produced by design consultants or specialist subcontractors who are responsible for their own specific portions of the work, can also be combined into a composite model showing the total of the project for visualization, coordination, and other purposes. A major challenge emerges, therefore, when these composite models are developed by collaborating teams using different software tools and often geographically dispersed, requiring that components, reference models, and software applications be interoperable.

Interactions are important in virtual building simulations, and various types of links may be established during the development of composed BIM models. Indeed, interactions refer to the interconnection of different sources of information. This information may be part of the 3D model, or it could be contained in another format separate from the model file itself, such as in a schedule, a spreadsheet, a database, or as a text document. Whenever the interaction involves the components of the 3D model, a common link in BIM needs to exist, i.e. the interoperability of various models that may have been created by different software tools is required (Grilo and Jardim-Goncalves, 2011).

Finally, a BIM-based project should be seen as a dynamic process. The approach of developing a 3D model with project information is, by the nature of the building and engineering overall life-cycle processes, a progressive elaboration, with different functions and derived benefits. BIM can support project collaborative working environments for enabling: *i*) the owner to develop an accurate understanding of the nature and needs of the purpose for the project; *ii*) the design, development, and analysis of the project; *iii*) the management of the construction of the project; *iv*) the management of the operations of the project during its operation and decommissioning.

3. BUSINESS INTEROPERABILITY IN THE AEC SECTOR

Whist interoperability is an important requirement for BIM-based projects, the goal of full interoperability is far from being realized, in the AEC sector. A study prepared for the National Institute of Standards and Technology (NIST) by RTI International and the Logistic Management Institute, to identify and estimate the efficiency losses in the U.S. capital facilities industry resulting from inadequate interoperability amongst computer-aided design, engineering, and software systems, estimates the cost of inadequate interoperability in the U.S. capital facilities industry to be $15.8 billion per year (Gallaher, 2004). The NIST study considered inefficiencies resulting from inadequate interoperability and includes manual reentry of data, duplication of business functions, and the continued reliance on paper-based information management systems. This study is an indication of the AEC industry's inability to exploit ICT to realize its full benefits.

Although there is considerable effort in interoperability standards development, there still exists today a failure to deliver seamless AEC interoperability. The AEC sector perspective on interoperability, like that of many other industrial sectors, is reductionist and unable to fulfill the promise of an interoperable business environment. Indeed, the AEC sector's efforts for interoperability have been very focused on data aspects of information systems. There is a need for AEC to extend the more technically focused notion of interoperability to cover the organizational and operational aspects of setting up and running ICT-supported relationships.

Indeed, interoperability is often discussed in the context of technical integration related to platforms, network devices and communication protocols, as well as syntactic and semantic data formats (Peristeras and Tarabanis, 2006). This is reflected by the most cited definition of interoperability that characterizes interoperability as ‘the ability of two or more systems or components to exchange information and to use the information that has been exchanged’ (IEEE, 1990). Over the last decade, internet and web service technologies have significantly fostered interoperability at the transport and communication level (Alonso et al., 2003).

But with the broader use of these technologies, a multitude of interoperability issues have to be solved at higher levels in order to allow for seamlessly integrated collaboration. Whereas many authors have underlined the need for aligning the semantics (Zhang, 2004), some of them consider interoperability in the broader context of value chain integration. Yang and Papazoglou (2000) mention business process compatibility, adaptability of business processes, leveraging legacy assets, support for business transactions and network security services as important factors driving interoperability in the context of e-commerce and integrated value chains.

While the technological interoperability research stream intends to solve the issues related to the electronic integration in heterogeneous, distributed environments, business interoperability research intends to determine how and to what extent the potential of these concepts can be reclaimed for realizing seamlessly integrated value chains. More recently, Enterprise Interoperability has been defined as “*a field of activity with the aim to improve the manner in which enterprises, by means of Information and Communications Technologies (ICT), interoperate with other enterprises, organisations, or with other business units of the same enterprise, in order to conduct their business. This enables enterprises to, for instance, build partnerships, deliver new products and services, and/or become more cost efficient”* (Li et al, 2006). Thus, Business Interoperability encompasses technological, social, procedural, legal and strategic aspects of collaborations.

Within the AEC sector there is a recognition of the need to address a context wider than just the technological issues of interoperability on BIM. This is the case of the Information Delivery Manual (IDM) of the IAI, which considers, in addition to the IFC’s standards, a methodology to support the implementation of BIM, addressing the business processes and information exchange requirements. IDM captures, and progressively integrates business processes whilst at the same time providing detailed specifications of the information that a user fulfilling a particular role would need to provide at a particular point within a project (IAI, 2011). To further support the user information exchange requirements specification, IDM also proposes a set of modular model functions that can be reused in the development of support for further user requirements. IDM describes a set of process maps, exchange requirements and functional parts, and has been recognized as the key feature that makes IFCs work. However, in spite of being a valuable development, it falls short of the broader needs regarding interoperability on issues such as intangibles, e.g., culture and values, or management of contractual relationships on project development.

4. THE BUSINESS INTEROPERABILITY QUOTIENT MEASUREMENT MODEL

The primary objective of this paper is to propose a model that allows the measurement of Business Interoperability to BIM-based projects, based on a holistic approach to the topic. The reasoning about the development of the Business Interoperability Quotient Measurement Model (BIQMM) described is the stance that technical and economical assessment approaches that are based on a static idea of collaboration relationship have limited impact (Li et al, 2008). Dynamic approaches that take into account the past trend, and hence the future increase in interoperability requirements, are more capable at judging the present state of interoperability 'preparedness'. Hence while using the BIQMM, these dynamic factors need to be taken into consideration.

The proposed model has identified eight major Business Interoperability Parameters (BIP) that represent the different levels of interactions that collaborating entities could engage in, and further identifying sub-parameters to enable performance measurement for each BIP (Figure 1). The model draws from literature review, and namely from the outputs of research projects that dealt with inter-organizational interoperability and collaboration and the full description of each parameter and sub-parameter can be found elsewhere (Zutshi et at, 2011).

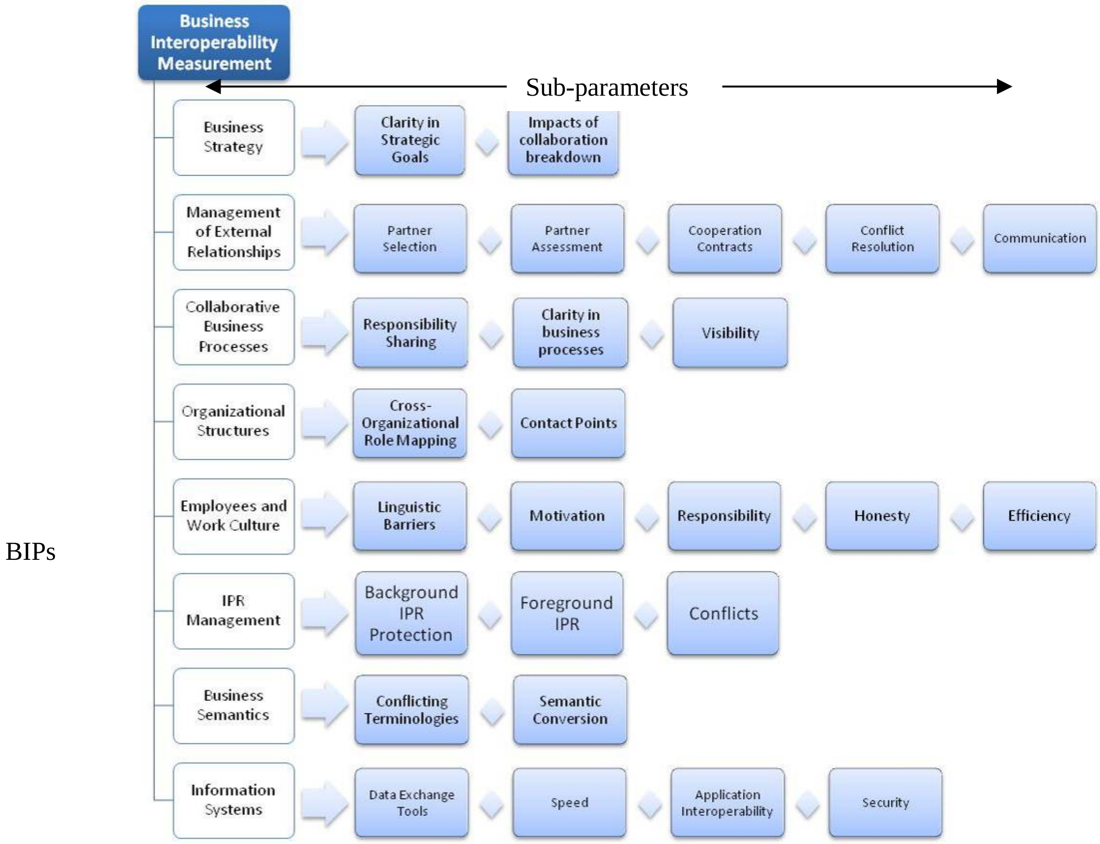

Figure 1 - Business Interoperability Parameters

Source: Zutshi et at, (2011)

The above model is designed to evaluate business interoperability between two agents and can be applied in any industrial contexts (Zutshi et at, 2011). In this model it is critical to assess the relevance of each of the eight identified BIPs and respective sub-parameters. The successful implementation of this model necessitates a precise assessment of both the relevance and performance of each BIP. The questions developed to gauge the performance of each attribute of a BIP in the next section, will guide the analysis of the correct collaboration situation.

The interoperability model encompasses several disciplines as it moves from the more technically focused area of Information Systems, upwards towards Business Strategies. The various fields of relevance are listed in Table 1.

Table 1 - Disciplines involved in BIQMM

Business Interoperability Parameter	Discipline(s) involved
Business Strategy	Strategic Management

Management of External Relationships	Industrial Management
Collaborative Business Processes	Business Process Management, Information Management
Organizational Structures	Organizational Management, Value Networks
Employees and Work Culture	Ethics, Sociology, Psychology, Behavioral Science
IPR management	Law, Innovation Management
Business Semantics	Information Technology, Language, Semiotics
Information Systems	Information Technology, IT Networking

BIQMM requires the assessment of multiple parameters and sub-parameters with respect to each collaborative scenario. For this purpose, it has been combined the BIP with the Analytical Network Process methodology. The ANP is a general theory of relative measurement used to derive composite priority ratio scales from individual ratio scales that represent relative measurements of the influence of elements that interact with respect to control criteria. Through its supermatrix whose elements are themselves matrices of column priorities, the ANP captures the outcome of dependence and feedback within and between clusters of elements (Saaty, 1999). The ANP provides a general framework to deal with decisions without making assumptions about the independence of higher level elements from lower level elements and about the independence of the elements within a level. In fact the ANP uses a network without the need to specify levels as in a hierarchy. Influence is a central concept in the ANP. It takes into account positive and negative consequences of feedback on the final decision. The ANP is a useful tool for prediction and for representing a variety of competitors with their surmised interactions and their relative strengths to wield influence in making a decision. The software package “Super Decisions” can be used to develop the demonstration model and all operations are performed by the software:

- Synthesize an ANP model taking into account the cross interactions between sub-parameters. All the clusters (parameters) are joined to the parent node “relevance” as the relevance of each of the sub-parameters and parameters needs to be evaluated with respect to the current business scenario. Additional influences as explained above need to be mapped also.
- Make Cluster Comparisons to assign relative importance between the parameters.
- Make node comparisons to assign the relative importance of each sub-parameter.
- The software develops the priority matrix and through it the final relative relevance scores for each of the sub-parameters can be obtained.

In this paper the model is applied to a BIM-based construction project on the basis of the above mentioned sub-parameters. The BIQMM can be used for different purposes in BIM-based context projects. It can be applied to select partners (architects, specialist designers, contractors), and suppliers for a specific project, whenever pricebased selection in not the prime factor; it can be used for selecting partners for long-term partnering for multi-projects; or it can be applied for selecting BIM platforms and project information management systems. The model provides not only a perspective of the current situation (as-is) but also the priorities and scope for improvement regarding business interoperability.

5. APLICATION SCENARIO

Construction agents (clients, architects, specialist designers, contractors, etc.) have often to make a decision between choosing a particular BIM technology solution or BIM platform for specific projects. However, rarely there is a concern to cope with business interoperability demands of BIM-based projects. These BIM solutions have direct implications on only a few sub-parameters of the BIQMM model. The sub-parameters interact with other parameters and the application of ANP lets us model these interactions to compute the performance of different choices. Thus using ANP to BIQMM, decision making regarding technology choices can be made.

The presented application scenario regards the analysis of the business interoperability on a construction project, during the design phase, where a set of agents (client, architect and specialist designers) will be using a BIM-based solution for supporting the collaborative processes. They wish to establish an BIM-based information system platform where building specifications and related availability of information can be easily and quickly exchanged, considering the assumption that there will be no need for the deployment of a unique software vendor. They also want the platform to be able to support the cost management and financial transactions information and hence the platform should incorporate some levels of security. It should also be able to cope with the use of different semantic terminologies for describing building elements and processes, without a uniformed set of terminologies (varying across each construction agent).

A decision between three BIM-based Platforms needs to be made. BIM Platform 1 incorporates high levels of security and encryption. BIM Platform 2 uses a light code and hence is much faster. Also it uses a better user interface that promotes easy visibility of information and is easier to use for people without much experience and training. BIM Platform 3 incorporates advanced Semantic Conversion capabilities and hence can be very useful for communication with diverse platforms. For the development of the ANP model (Figure 2): Semantic Conversion, Data Exchange Tools, Security, Speed, and Visibility nodes are connected to the three alternatives, since the chosen technology directly influences these parameters. Pairwise comparisons are then performed to obtain the scores. Table 2 shows these scores taken from the supermatrix.

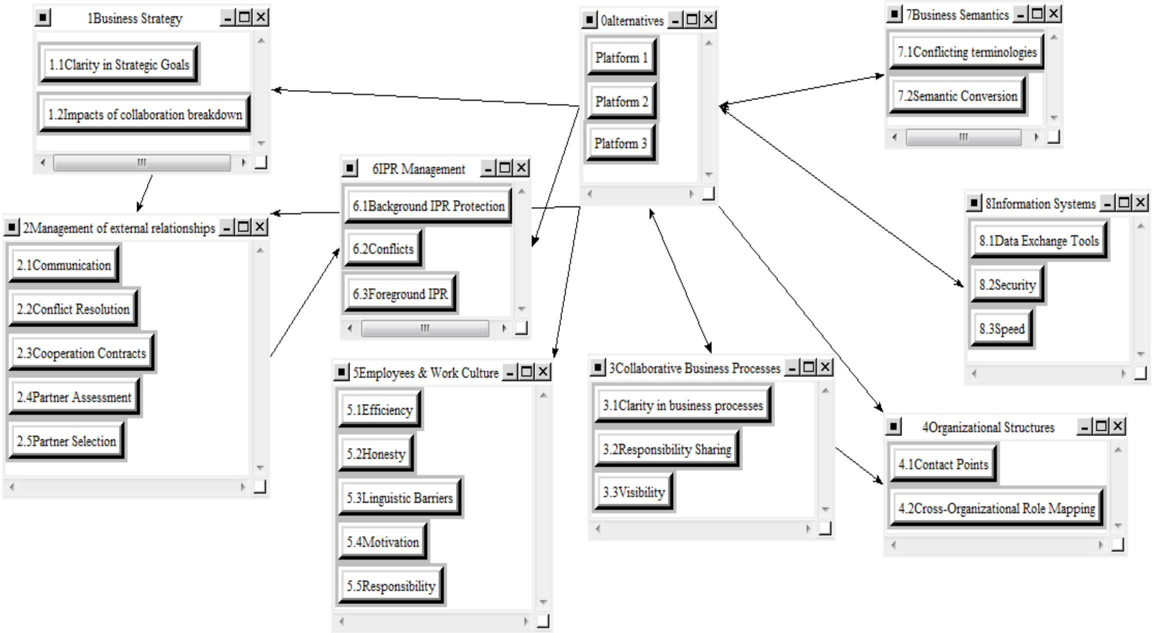

Figure 2 - Network for application scenario 2

The pairwise comparison is conducted with semi-structured interviews with the project agents, grounded on the technical aspects of each BIM-based platform and the specificities of each company information systems and the details about the vairous sub-parameters considered. As there is a need to have an aggregated perspective, the analysis is done for each company and then an average is obtained to compute the result.

Table 2 - Supermatrix elements showing nodes having direct relations with success criterion

	3.3 Visibility	**7.2 Semantic Conversion**	**8.1 Data Exchange Tools**	**8.2 Security**	**8.3 Speed**
BIM Platform 1	0.109	0.113	0.261	0.438	0.238
BIM Platform 2	0.581	0.285	0.362	0.238	0.625
BIM Platform 3	0.308	0.651	0.376	0.323	0.136

“Super Decision” software is used to compute the Super Matrix and the Global Limiting Matrix as for the previous application. The Node Priority table in Supermatrix is selected within the software as shown below in Table 3. From the node priority table, Table 3, it can be seen that BIM Platform 2 is the most preferable option. Hence it can be deduced that for this collaboration scenario, BIM Platform 2 will boost the overall interoperability, while taking into account the complex interactions of the lower level interoperability parameters with the upper levels. One of the implications of this model is that organizations can maintain a scoring of different interoperable parameters beforehand. When a decision needs to be taken that directly impacts only the lower levels, the pre-existing model can be invoked to compute its impact on upper levels as well. Thus the modeling of complex inter-organizational interactions could prove as a helpful tool for quick decision making at one part of a large organization without repeatedly re-assessing its implications on the whole organization.

Table 3 - Node Priority Table for Application Scenario

Name	Normalized By Cluster	Limiting
Platform 3	0.36524	0.100132
Platform 1	0.17004	0.046618
Platform 2	0.46471	0.127401
1.1Clarity in Strategic Goals	0.28653	0.008331
1.2Impacts of collaboration breakdown	0.71347	0.020744
2.1Communication	0.14856	0.027148
2.2Conflict Resolution	0.29095	0.053171
2.3Cooperation Contracts	0.28017	0.051201
2.4Partner Assessment	0.11641	0.021274
2.5Partner Selection	0.1639	0.029953
3.1Clarity in business processes	0.14249	0.016145
3.2Responsibility Sharing	0.63076	0.071471
3.3Visibility	0.22676	0.025694
4.1Contact Points	0.31129	0.047987
4.2Cross-Organizational Role Mapping	0.68871	0.10617
5.1Efficiency	0.18536	0.00753
5.2Honesty	0.29621	0.012033
5.3Linguistic Barriers	0.23681	0.00962
5.4Motivation	0.07988	0.003245
5.5Responsibility	0.20173	0.008195
6.1Background IPR Protection	0.25951	0.04446
6.2Conflicts	0.04911	0.008413
6.3Foreground IPR	0.69139	0.118452
7.1Conflicting terminologies	0.4944	0.008872
7.2Semantic Conversion	0.5056	0.009073
8.1Data Exchange Tools	0.4892	0.008153
8.2Security	0.22447	0.003741
8.3Speed	0.28633	0.004772

6. CONCLUSIONS

The contribution of this paper is the introduction of an interdisciplinary approach supported by a model based on metrics to business interoperability in the context of BIM-based projects. It is advocated in this paper that the approaches that use information theory and IT based tools to address interoperability fall short of in-depth analysis of the real problem for the deployment of BIM in construction projects. Hence expertise from several disciplines, including Management, Law, Sociology, Psychology, and Engineering need to be engaged before a comprehensive model for assessing and addressing business interoperability is evolved. Another key contribution of this paper is the proposal of Business Interoperability Quotient Measurement Model (BIQMM) that attempts to evaluate the overall BIM-based projects business interoperability by identifying a series of interoperability parameters and sub-parameters. The application of a multi-criteria decision making tool, the Analytical Network Process, which provides a comprehensive framework for interoperability measurement is proposed. A comprehensive approach to AEC business interoperability has had very limited research. Further investigation into defining relationships between business interoperability and true AEC performance improvements and subsequent economic benefits derived from BIM-based approaches needs to be performed.

ACKNOWLEDGEMENTS

We would like to thank to Fundação da Ciência e Tecnologia for funding our research units.

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