A comparative approach to map BIM workflow in US mid-size firms using BPMN and IDEF methods

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ABSTRACT: This paper is a part of an ongoing research that is motivated by the increasing need for business process improvement in the competitive AEC industry and Building Information Modeling (BIM) implementation. Thus, the main objective of this research is to develop an explicit and flexible Business Process Model (BPM) for midsized architectural firms that are adapting to the wide scale implementation of BIM. The BIM business process model developed through this research could serve as a reference model for restructuring many architectural firms.

The general outcome of this paper is a comparative description between two methods of mapping the existing work flow of BIM using The Business Process Modeling Notation (BPMN) and the Integration DEFinition (IDEF), as derived from expert questionnaire and two BIM case studies. The paper focuses on the Schematic Design (SD) and Design Documents (DD) phases inside mid-sized architectural firms in USA.

The first objective of this paper is to map the existing BIM business process model for midsized architectural firms, and to discuss the adapted criteria, a step to fill the research gap in the academic field. The second objective is to measure the level of interactivity between the two generated business process models and various BIM users, in order to establish an effective modeling approach to develop the existing BPM. It is highly expected that through the development and implementation of this new model, the use and functionality of BIM will be enhanced.

KEYWORDS: Building Information Modeling (BIM), Business Process Modeling Notation (BPMN), Integration DEFinition (IDEF), Schematic Design (SD), Design Documents (DD)

INTRODUCTION

Today, there is little doubt that Building Information Modeling (BIM) is a new technology that is reshaping the building industry. BIM has emerged as a useful tool for architects, engineers, and contractors in the delivery of new constructions. BIM is an innovative tool that most design and construction professionals do not currently use on a regular basis. According to the Smart Market report, in 2008, architects were the most frequent BIM users with 54% usage (McGraw-Hill 2008). However, as those professionals increase their understanding of BIM and its capabilities, BIM will likely become a part of common design and construction practices. On the other hand, BIM, like many other products in the project management software industry, currently faces significant issues and obstacles that prevent its widespread use. These issues include inappropriate adaptation strategies, old management and organizational structures, and slow software development (McGraw-Hill 2008). There arises the need for businesses to assess and rethink their existing BIM implementation processes, communication mechanisms and information flow strategies in order to fully avail themselves of the opportunities that BIM has to offer. This may involve the means to smoothly shift from existing CAD platforms, and how to find the precise changes that can prompt architectural offices to improve their existing business processes, and develop strategies that are flexible enough to incorporate BIM as it evolves.

Based on these requirements, this paper focuses on the need of mapping the “As-is” BIM implementation workflow that are currently exist in mid-sized architectural firms as they relate to how information flows, BIM related activities and the existing business processes model. For this, two case studies and several interviews were conducted. The case studies and the interviews findings helped to develop the existing business model and to identify challenges associated with BIM implementation, and the potential areas for improvement, especially those ineffective processes at the departmental boundaries.

1.0 Business Process Modeling

Business Process Modeling (BPM) is commonly a diagram representing a sequence of activities that shows sequential events, actions and links or connection points. The term ‘process’ can be defined based on the subjected field of interest. For example Harrington (1991) defines the term “process” as “any activity or group of activities that takes an input, adds value to it and provides output to an internal or external customer. Processes use an organization’s resources to provide definitive results”. Davenport (Lineberger and Marwick, 1993) states that “a process is simply a structured, measured sets of activities designed to produce a specified output for a particular customer or market”. Although the Business Process Modeling has different approaches, the main approaches are the Business Process Model and Notation (BPMN), the Unified Modeling Language (UML) and Integrated Definition (IDEF) modeling. According to Dana Smith, the most common approaches that are being used in the AEC industry are the BPMN and IDEF. For a better

more elaborative definition of these approaches the next section will provide a detailed discussion (Smith and Tardif, 2009).

1.1. Business Process Model and Notation (BPMN)

Business Process Model and Notation (BPMN) is a graphical representation approach and modeling method for mapping business procedures. It is also known as Business Process Modeling Notation. This approach was first introduced by Business Process Management Initiative (BPMI), but currently it is being developed by the Object Management Group after the two organizations merged in 2005. The latest version of BPMN is 2.0, as of March 2011. This version works based on a flowcharting technique, which is very similar to activity diagrams from the Unified Modeling Language (UML). The BPMN approach is one of the most powerful languages used in representing information flow, interdependencies of roles, and sequence of activities, which helps many organizations in the building industry. A BPMN is presented in common graphical languages that bridges communication gaps and unifies graphic notation while considering the complexity of business execution languages, and particularly Business Process Execution Language (White, 2006). Moreover, the widespread adoption of the BPMN and the variety of competing standards help to unify both basic and advanced business process concepts in one diagram. Thus, many architectural/construction organizations are giving more attention to the BPMN approach (Smith and Tardif 2009). As shown in figure 1 in the Business Process Diagram, there are a number of graphical elements with which we represent a business process. Within these elements are the activities that represent the work that was carried out, the beginning and end events, which indicate the starting point and completion of the process, plus the decision elements known in BPMN as Gateways, which indicate alternatives along the way. These elements are connected by means of Sequence Lines that show the process flow.

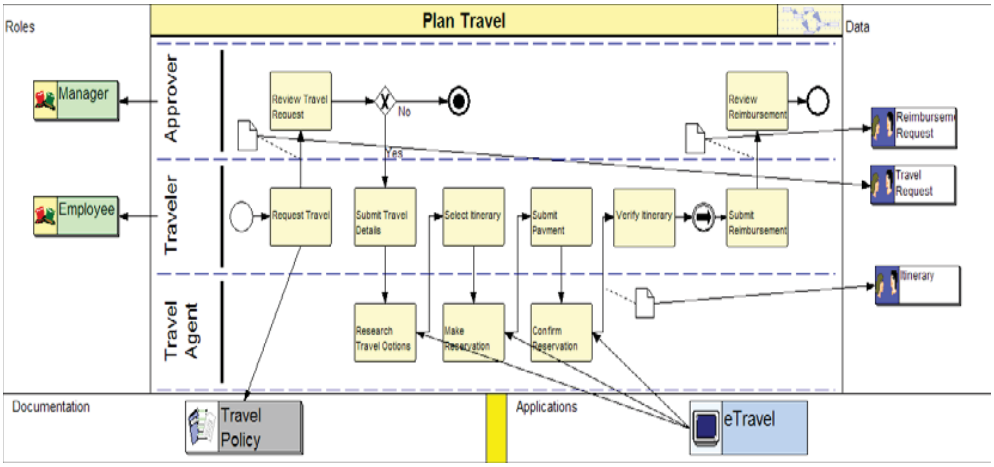

Figure 1: Business Process Model and Notation for a process with a normal flow. Source: (Sowell 2009)

1.2. The Integrated Definition (IDEF)

IDEF is a business process modeling approach that was first initiated and developed by the U.S. Air Force in the 1970s to cover a wide range of uses, from functional modeling to data simulation, object-oriented analysis-design and knowledge acquisition. As a widely used functional modeling approach for engineering purposes, this approach is being used in the architecture/construction industry as a modeling approach to map and analyze the functions and activities for the design/construction process (Savage 1996, p: 84). The Integrated Definition (IDEF) has at least fourteen versions but the most-well known and widely used of the IDEF family are IDEF0 (a functional modeling language building on SADT) and IDEF1X, which address information models and database design issues. The IDEF0 was derived from the graphic modeling language Structured Analysis and Design Technique (SADT) as developed by Douglas T. Ross and SofTech, Inc. (Ward 2009) to model the decisions, actions, and activities of an organization or system. In the architecture/construction industry, IDEF0 represents functional modeling by tracing the Inputs, Controls, Outputs and Mechanisms (ICOMs), which captures the important data flow for each activity, resulting in a hierarchical series of diagrams, and text cross-referenced to each other. Usually, the primary modeling components (activities) are represented on a diagram by boxes, and the data (inputs/outputs) that interrelate those functions is represented by arrows. The diagrammatic representation of IDEF0 methodology can be seen in Figure 2.

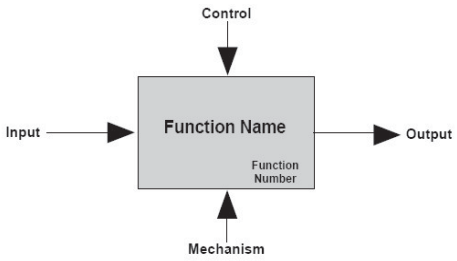

Figure 2: IDEF0 Notation Source: (Defense.Acquisition.University 2001)

2.0. OVERVIEW OF RESEARCH DATA COLLECTION

Yet, this paper will provide an overview of the existing BIM (As-is) process model, which presents the communication mechanisms and data flow related to BIM inside the subjected firms using two modeling techniques, BPMN and IDEF. In order to map the existing BIM workflow, the researcher conducted two case studies and several interviews in an attempt to map those challenges for mid-size firms. For the case studies, the sampling process was initiated by gathering information about the specifications of the mid-size architectural firms in the USA. Then, the researcher selected two mid-size firms that follow the research sampling criteria. The first case study was conducted in a mid-size firm that is located in Norfolk, VA and contains 37 architects and employees, while the second firm contains 48 architects and related employees. The researchers entered both firms as an investigator after receiving Virginia Polytechnic Institute and State University (Virginia Tech) Institutional Review Board (VT IRB) approval. During case studies, the researcher observed the day-to-day operations, team interactions and communication exchanges as they relate to project design development and construction management using BIM. Moreover, the researcher conducted seventeen interviews started with one or two interviewees and then proceeded with parallel data analysis to avoid being overwhelmed by massive amounts of information, which emerged and were updated during data collection. Furthermore, the questions that arise from the first interview helped to develop and guide the adjustments for the next round of interviews (Strauss and Corbin 1998).

2.1. Types of data collection methods

The researcher adopted a dual approach to collect data, by carrying out both interviews and case studies, which helps to increase the validity and reliability of the data, as the strengths of one technique can counterbalance the weaknesses of another. Another reason to adopt this dual approach is that the case study strategy can be criticized because of the lack of measurability. Thus, the researcher applied the case study technique in this research to analyze different variables relevant to the studied phenomenon (Key, 1997). Furthermore, mapping a business process flow requires tracking and mapping of information exchange between BIM users and other various complicated activities, which have to be mapped within existing environments. So, two case studies were conducted to map BIM related process modes, however the duration of the case studies was not long enough to develop a business map for the entire BIM related activities. Thus there was a need for collecting more data using interviews to develop a complete preliminary “As-is” business process model thus another round of interviews (structured interviews) was conducted (Jan 2011- Oct 2011), where interviewees were asked to recall their roles and activities inside the targeted firms, as well as to describe the routes of information flow and how decisions are made.

On the other hand, extensive interviews (semi-structured and structured interviews) with numerous BIM stakeholders have been conducted for different reasons; to provide rich and relevant data on the research subject, and also to cover any lack of information from the case studies, to achieve the generalizability of the process model, and to share common characteristics of the mapped business model with other mid-sized architectural firms.

2.2 Interview mechanisms

Using interviews as a tactic, the researcher initially sent an email that contained an overview, targets, and expected outcomes of the research to the BIM manger in the subject firms. Interviews began with a top-down management strategy: The researcher started by interviewing stakeholders and BIM/project managers in the targeted firms, and then proceeded to the operational staff and other BIM stakeholders (Cai, 2007). At the end of the first interview, the researcher asks BIM/project managers to introduce key persons in their BIM related business process. In the first round of interviews, participants were asked to freely express their thoughts and ideas concerning BIM related issues. This data, in addition to data obtained from the case studies, were later coded and interpreted to provide sufficient information that helps to build a holistic understanding of the As-is BIM related business process model. While the second round of interviews was conducted to complete the layout of BIM related workflow.

2.3 Interviewees demographics

The interviews took place over the course of seven months from November 2010 to June 2011 with a total of 12 interviewees. Some of the interviews were conducted over the phone and the others were in personal.

The following table summarizes the interview process. The table represents participants' demographics based on their BIM activities, experience, interview types and durations.

Table 1: Interviewees Demographics

Participants	Discipline	Firm 1	Firm 2	Out of case studies Firms	Work Experience in years	Interview Mode	Interview Media	Interview Duration hh:mm:ss	Interview Rounds	
									Round 1 (BIM Issues)	Round 2 (As-is model)
Participant (1)	BIM manager	*			15	Semi-structured/ Structured	Personal	01:01:33 00:31:02	*	*
Participant (2)	BIM manager		*		10	Semi-structured/ Structured	Personal	00:47:17 00:24:52	*	*
Participant (3)	Architect	*			3	Semi-structured	Personal	00:51:50	*	
Participant (4)	Architect			*	4	Semi-structured	Personal	00:33:21	*	
Participant (5)	MEP	*			3	Semi-structured/ Structured	Phone	00:55:01 00:23:42	*	*
Participant (6)	HVAC	*			5	Semi-structured/ Structured	Phone	00:45:38 00:26:29	*	*
Participant (7)	Architect			*	3	Semi-structured	Personal	00:25:32	*	
Participant (8)	Architect			*	3	Semi-structured	Personal	00:21:41	*	
Participant (9)	Architect		*		2	Semi-structured	Personal	00:31:38	*	
Participant (10)	MEP		*		8	Semi-structured/ Structured	Personal	00:41:10 00:29:51	*	*
Participant (11)	HVAC		*		`4	Semi-structured	Phone	00:55:21	*	
Participant (12)	Contractor			*	13	Semi-structured	Personal	00:24:11	*	

2.3. Case study sampling:

According to "revitinside.com" (last update: June 2, 2010) 500 of registered architectural firms are using BIM not only as the design delivery tool but also as a collaboration tool. This represents 2.5% of total the registered architectural firms in the USA in 2010. There are at least 20,000 architectural firms in the USA. Characteristics of Case studies can be identified as the following:

Firm Type: The subjected firms are mid-size architectural firms in USA. The firm should contain 5 to 50 employees organized structurally in different departments such as design, production, business development, and construction administration.

Firm Experience: The subjected firms should have variety of business services in addition to its ability to complete technically challenging projects. Also, the firm should be able to conduct simulations and comparative analysis, either environmental to measure the facility's predicted performance, or construction simulation for sequencing the construction process. Moreover, it should also have the ability to manage and produce construction documents and specifications, and to follow up the construction progress.

Project types: As previously mentioned in chapter one of this dissertation, this study focuses on mid-size to large-scale projects (commercial buildings, educational, etc.). These projects were chosen as a limit for this research for two reasons. The first one is that the number of communication issues that might typically emerge in mid-size to large scale projects is more than for small-scale projects. Secondly, adapting BIM as a new technology in contemporary architectural firms adds cost of running a new system to the overall project cost.

Firm Clients: The firm should have a broad range of clients (e.g. the government, private developers) and supervise various project types, such as industrial and civil facilities. This wide range of business patterns will provide multiple attributes in the business processes that can be found in other mid-sized architectural firms in the USA.

BIM manager: Although every organization may have different functional departments, head and CEO, it is important for the subjected firms to have a BIM manager, who is able to facilitate all the process necessary to manage BIM, understands the workflows, who has a technical knowledge of BIM applications used and also has strong communication skills.

The first subjected firm is located in Norfolk, VA and contains 37 architects and employees and a BIM manager who has a very good experience with BIM issues, helping to cover a lot of communication problems inside the firm. The subject project is the "West Virginia Medical Center". The architectural teamwork of this project consists of at least one member to fill the following categories; shell, enclosure,

interior, site and custom objects (People work in separate tasks). The MEP team has four engineers; HVAC, fire protection, electric, and plumbing engineer, while the structural team has three engineers who are working on structural design and structural analysis. The second subjected firm contains 48 architect and employees. The subject project is the " Medial Center in WV, USA" From both case studies it will be clearly shown that BIM could be a constraint when not implemented probably. The researchers entered both firms as an investigator from June 2010 until April 2011, after receiving Virginia Polytechnic Institute and State University Institutional Review Board (VT IRB) approval.

3.0 Mapping BIM "as-is" workflow – schematic design phase

With the aid of different data resources, including; researcher's notes, diagrams and memos that were gathered during the case studies, in addition to the interviews that were conducted to understand BIM activities and tasks in the Schematic Design phase, the researcher was able to map BIM workflow as the following.

The workflow usually starts once the client initiates the need for the project. Usually, the client has preconceived knowledge of the project's purpose and what benefits should be achieved. Then the process inside mid-size firm starts with preparation of the project brief and the establishment of stakeholders' involvement which is followed by the appointed BIM manager who starts an overall process review, that includes planning, managing project documents, and preparation of the project brief. After preparing the project brief, the next step is the "bubble diagram", followed by the start of schematic sketching that is requested by the project manager, who typically assigns someone to get the proposal/proposals schematically into Sketch-Up. At this point the model typically only represents the project proportion and massing. Once the Sketch-up model reaches the final stage of the conceptual design, the architect usually has a meeting with the client to agree upon the layout. At the same time the project manager assigns another person with the task of laying it out schematically on Revit (Pre-Schematic Drawings). Once the model is transferred to Revit, the process goes back and forth between the appointed BIM manager and the architectural team to develop the concept and basic framework for the design of the project. The model will also be developed to provide "preliminary LEED documents". The next step is to prepare the preliminary feasibility study, which should be reviewed and approved later by the BIM manager. If the preliminary feasibility study is accepted, the execution plan and design management report (including design process, budget and schedule, communication protocols as well as roles and responsibilities of the various parties) will be presented to the client for the "Schematic Design Approval". Then, if the client approves these documents, they can proceed to the next phase of the project.

4.0 Mapping BIM "as-is" workflow – design development phase

The Design Development phase involves more inputs from different disciplines. Typically, these inputs are not found in the Schematic Design phase and may include the development of architectural drawings, structural drawings, building services drawings (MEP+HVAC), fabrication drawings and cost estimation. Thus, this phase is more interlinked than the Schematic Design phase and its process model tries to represent dependencies and overall information flow from different disciplines. The existing model for this phase can be summarized in the following steps: After the approval of the schematic design, the architectural team develops the BIM model to illustrate more in-depth aspects of the proposed design; they also verify that the proposed design complies with US building codes and LEED project compliance. After this revision, the project stakeholders usually have a "kick off meeting", in which they identify the project keys, such as; each stakeholder's responsibility, scopes, standards, who's modeling what, levels of detail, push for extra time and fee if it's more than you've budgeted, etc. Typical to the case study, and in the "best case scenario", the appointed BIM manager sends the BIM model to the MEP team so they simultaneously start MEP and HVAC design earlier at the beginning of the design development phase. Thus, the MEP team starts the development and expansion of the mechanical Schematic Design documents and criteria for lighting, electrical and communications systems that have been suggested by the architectural team. Upon the approval of the MEP and HVAC feasibility study, the BIM manager sends the model to the structural team. After making the required changes, the last step on the structural design is to prepare the feasibility study. Once the feasibility study is accepted, the BIM manager will review the whole business process and project documents. At this time, the architectural team works on landscape design and documentation services as well as the development of outline specifications or materials lists to establish the final scope and preliminary details for on-site and off-site civil engineering work and landscaping work. The next step is the review of the process by the BIM manager. Upon approval, he/she sends the BIM model or the generated project documents to the project manager and the architectural team to review the feasibility case study, prepare the design coordination strategy and cost documents. If the cost estimation needs updating, which may require design changes, the process once more starts again from the beginning by updating the architectural design, which subsequently may require further changes in MEP or Structural Design. The final step in the design development phase is the project review, which includes reviewing project delivery procedures, construction sequencing, and also review and update previously established schedules for the project. Then client approval is obtained before proceeding to the Construction Documents Phase. Figure 3 summarizes the design development workflow.

5.0. MODELING AS-IS WORKFLOW

The BIM workflow has been generated using the BPMN and IDEF methods. Both methods describe the sequence of activities and the flow of information in more details. It should be noted that any As-is model is composed of different levels of details, which could reveal some confidential information about the case study firms. Thus, the As-is model here does not show the BIM activities in detail, however the constraints associated with the workflow are summarized. The model was distributed to a sample of BIM stakeholders upon their requests for more information about BIM procedures and also to compare BIM functions from one firm to another. At this point, the researcher had to go into each business component to explain in detail, such as activities, decisions, communication types, 'performed by whom', and the flow of information. This helped the researcher to get more specific comments and feedback concerning how BIM stakeholders see the existing model and also to identify the problems, which limit a more complete BIM implementation. The proposed model can be used in cases of process improvement in the future. It is important to mention that the details of the As-is model are not listed in this thesis to protect the privacy of the case study firms. It is important to mention that the researcher requested the interviewees' feedback of the envisioned BIM related "To be" workflow from two groups; the first contained some BIM users who contributed to the study from the start. In addition, the BIM workflow was presented to a second group of interviewees, which included not part of the model development. The new model was sent out in both IDEAF (to summarize the process) and BPMN formats to provide interviewees with the capability of understanding BIM business procedures in a more detailed graphical notation, in addition to facilitate the understanding of the performance collaborations and business transactions between the different process components.

6.0 RESEARCH FINDINGS

Having used both the IDEF and BPMN modeling techniques for the "As-is" BIM related process workflow, it was discovered that interviewees are not very interested in an IDEF model to represent workflow but were more interactive with the BPMN model, citing that BPMN was easier to understand. In addition, it provides greater detail about the BIM related workflow, inputs, outputs, actions, tasks and who is doing what, which is vital for the overall comprehension of the workflow. Thus, the presentation of BIM workflow in this paper will be limited to BPMN technique. Usually, IDEF0 diagrams have to be presented to interviewees followed by an explanation of the modeling syntax from the researcher. Without this explanation, it is expected to initially get un-precise, confused or wrong feedback from model readers', which subsequently might cause many users to reject the model at the beginning.

6.1. Advantages of IDEF modeling approach

The major advantage of using IDEF0 is that it consists of a decomposed system, which is found to be easily understood and instantly read. It was found that IDEF0 model saves time that would be spent on the explanation and training of reviewers. Also, this allows the inclusion of a large number of comments from BIM players at one time. The direct contact between the researcher and BIM players allows an efficient development and fluent integration of comments and suggested changes from a large number of reviewers. The arrangement of boxes (activities) does not require a strict sequence, which gives the possibility to manage feedbacks between activities. Also, several activities can occur in parallel to each other, or in sequence depending on a specific activity accomplishment.

6.2. Disadvantages of IDEF modeling approach

Because of the simplicity and readability of the IDEF0 model for non-professionals, this typically doesn't present details for more complicated processes. For example, one of the rules in IDEF0 is that each diagram should consist of between 3 to 6 boxes, which makes it difficult to describe more than 6 activities for each diagram without becoming trivial.

6.3. Advantages of the BPMN

Having more details than the IDEF model, which helps to instantly identify problems in the sequencing or assignment of activities to performers. BPMN uses a swim-lane notation, showing the activities within swim-lanes that indicate each performer's activity, which gives a clear vision about the workflow and "what's going on? And who does what?" to model analysts. When compared to IDEF, BPMN is a more structured, composed, coherent and consistent way of executing and continuously changing end-to-end business processes. BPM usually shows the composed sequence of activities in one diagram and involves all the workflow resources and components in light of their contribution to business performance in the same model. BPMN activities require a strict structure and composed sequence; BPMN combines the Activity Model with the Scenario Sequence Model at the same time.

6.4. Disadvantages of the BPMN

Because the BPMN is quite complicated, and usually combines activities, tasks, processes, sub-processes and other workflow details in one model, model readers' usually get confused and get lost in the diagrams. Because the model usually contains unlabeled arrows and symbols that connect and present BPMN activities, the relationships between these activities may be less apparent and difficult to read by nonprofessionals.

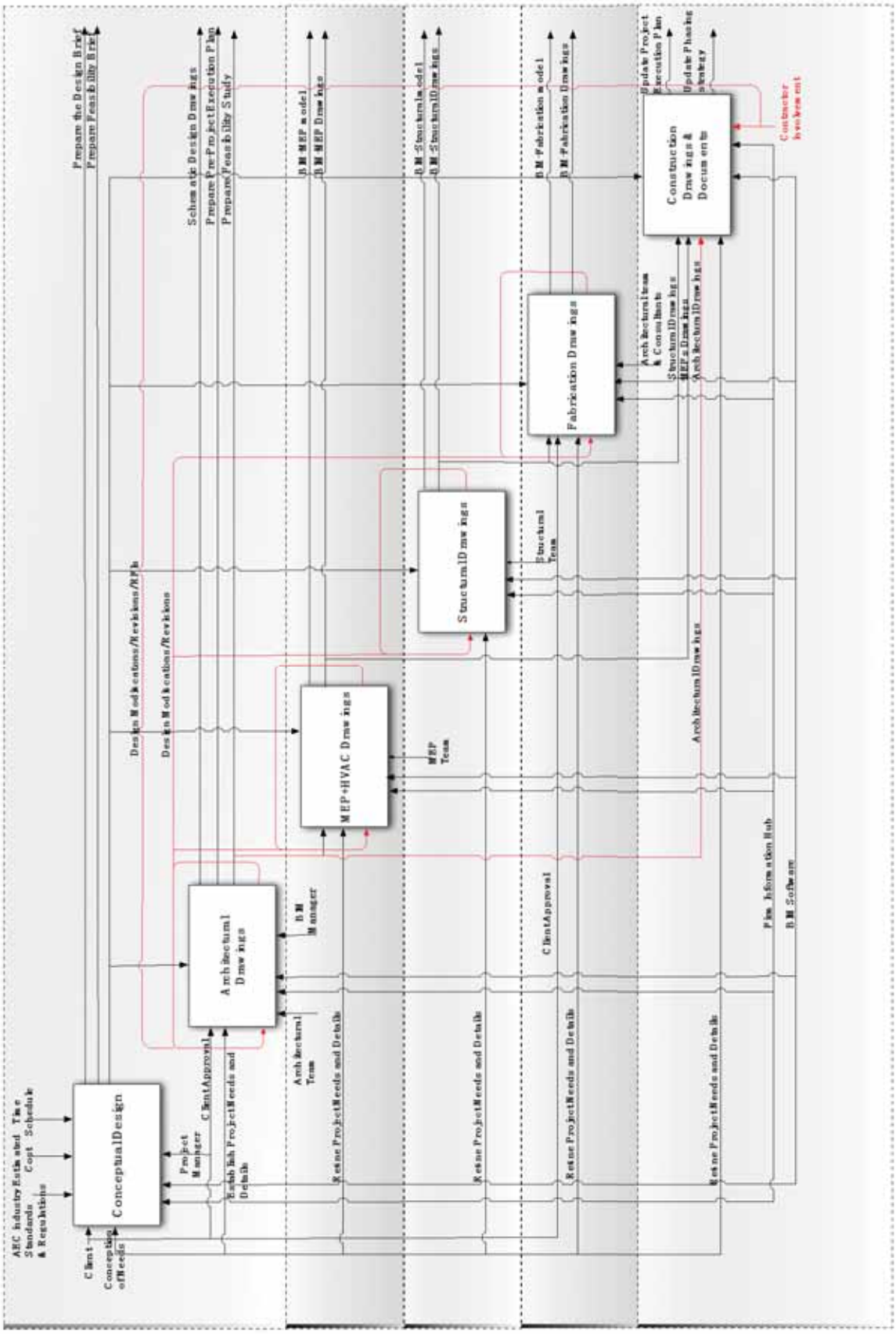

Figure 3: The existing BIM process model using IDEF0.

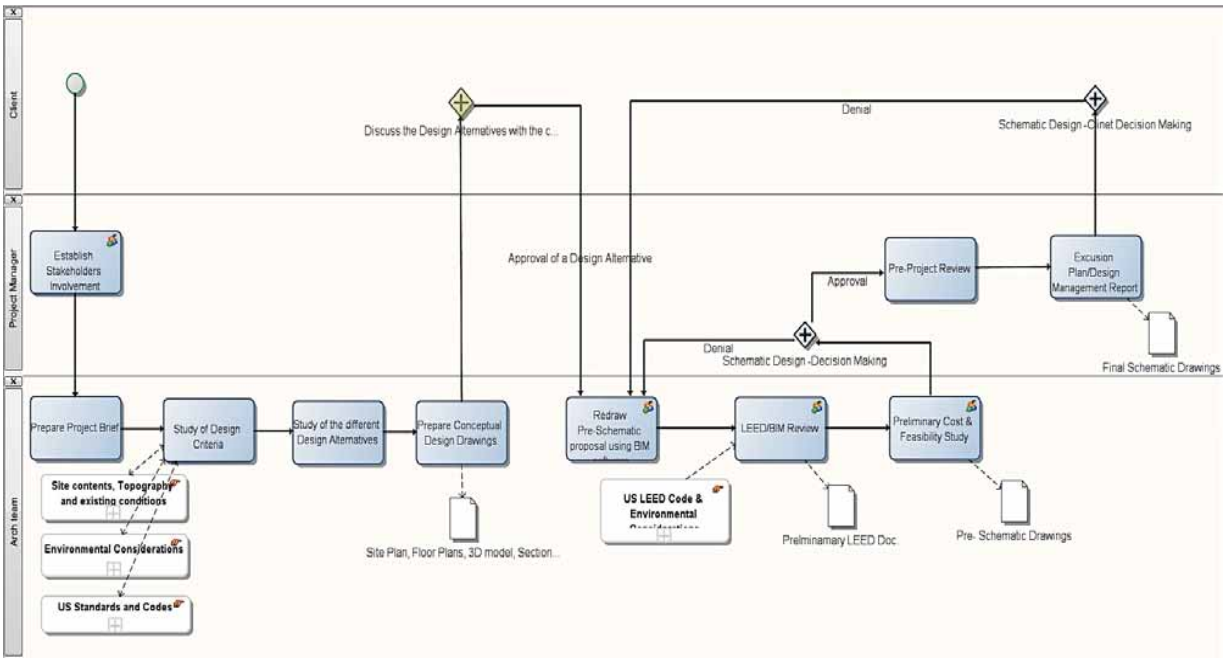

Figure 4: The existing BIM process model using BPMN– Schematic Design Phase.

CONCLUSION

There is a need for new business process models that supports Business Process Re-engineering (BPR) for BIM. The need has emerged for a new business process model, which is able to illustrate how, with the use of BIM, different members of a mid-sized architectural firm could derive benefits and overcome traditional process inefficiencies. In order to effectively adopt BIM in such firms, a redefinition of their current business model is required, one that could lead to a significant change in the work practices.

Thus, this paper focuses on mapping the existing BIM process model and identifying how it functions using two different techniques. The paper explores two of the most popular modeling theories, IDEF and BPMN, and compares between their advantages and disadvantages to help chose one mapping approach for this research. Moreover, it gives reasons for the rise of process modeling in the AEC industry and discusses the criteria for using two modeling approaches, and then presents a comparison between the advantages and disadvantages of each approach.

REFERENCES

A.I.A (2008) E202™–2008 Building Information Modeling Protocol Exhibit.

Eastman, C. M. 2008. *BIM handbook : a guide to building information modeling for owners, managers, designers, engineers, and contractors*. Hoboken, N.J., Wiley

Howell, I. B., Bob 2006. *Building Information Modeling Two Years Later –Huge Potential, Some Success and Several Limitations*.International Journal Of Architectural Computing 04(04).

Hsiu-Fang Hsieh, S. E. S. 2005. *Three approaches to qualitative content analysis.* Qualitative Health Research. Qualitative Health Research. 9

McGraw-Hill. 2008. *Smart Market Report, Building Information Modeling (BIM)* Building Information Modeling Trends SmartMarket Report.

Smith, D. K. and M. Tardif. 2009. *Building information modeling : a strategic implementation guide for architects, engineers, constructors, and real estate asset managers*. Hoboken, N.J., Wiley.