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Analysis of the adoption rate of Building Information Modeling [BIM] and its Return on Investment [ROI]

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Abstract

In an effort to remedy the issue of stagnant labor productivity in the construction industry, Building Information Modeling was proposed in the late 80's as a new solution for streamlining the design and delivery process of construction projects. BIM is a digital representation of a building meant to serve all project participants as a repository of all relevant data throughout the project's lifecycle. Management of this data along with the collaborative nature of BIM has been shown to offer many potential benefits to those involved in the project. Despite the huge potential for increasing productivity as well as the overall efficiency of construction projects, the adoption of BIM throughout the industry has been observed as slower than expected. This paper explores and analyzes the various barriers hindering the widespread adoption of BIM throughout the industry as well as proposes methods for addressing them. The author then answers the question of who should be responsible for driving the adoption of BIM and how to effectively do it. Finally the author proposes areas of further research and development which will assist in achieving a more widespread adoption of BIM throughout the industry.

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Keywords: Building Information Modeling; Adoption Rate; Barriers; Return on Investment.

1. Introduction

The AEC-industry is characterized by a collaborative effort to bring together qualified persons of varying professional backgrounds with the intention of turning visions into reality through the development of construction

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projects. However, it is argued that the overall labor productivity of the AEC-industry is declining [26] with a linear trend of about -0.32% per year (1964 – 2012). In many projects there is a lack of integration of design and construction, often coupled with poor collaboration amongst team members. As a result of this a lot of projects are over budget and/or behind schedule. The traditional two-dimensional design delivery system proves to be an insufficient method of communication of information between all of the parties involved.

Recent advancements in Information Technology processes have enabled the development of Building Information Modeling. BIM was developed as a means of tackling the issues contributing to inadequate levels of productivity in the AEC-industry. It is perceived as a next-generation solution for streamlining the delivery process of structures and a method of managing and accessing common building and facilities information throughout the project lifecycle. Drawings are no longer the repository for design information, but are rather simply reports of the design information, and their production is almost entirely automated [1]. The development of an integrated model enables more stakeholders to take part in the early phases of the project's development. This is practically not possible with a fragmented development team. The various stakeholders can contribute their personal business and engineering knowledge and expertise into the project's design, scheduling, and organization; thus enhancing all phases of the project. The result of this is a data-rich and object oriented model which acts as a data repository of the structure which can be accessed by the objects users throughout its lifecycle.

Unfortunately the adoption rate of this new technology has been slower than anticipated, despite the large amount of research which has been dedicated to BIM's development. The factors contributing to this vary from project to project and are difficult to identify accurately. Although numerous barriers to adoption have been identified, there still is a need to further understand their impact on adoption and how they behave when combined.

2. Literature Review

Building information modeling over last decade have been subject of interest of researchers and in consequences of literature [20]. There are many subjects e.g. [20] concerning efficiency of the planning and design process, [3,4,10,20,21], construction planning and control [10,19,25] design and integration [2,10,23], facility management [9,10] and also building related process [10]. After analysis over 600 sources of information with goals related to determination and measurement of BIM benefits and concerning results or data of such as measurements from real projects only more than 20 were remained with information concerning some benefit of BIM implementation and 4 were based on case study data [7,14,16,17].

Majority of publications concerning BIM adoption comes from vendors of BIM applications, guidelines and official institution reports and also there can be pointed out only few examples of adopting in real projects [14]. There is a lack of any cross-case synthesis leading to enhanced benefits to projects beyond the individual case consideration and the referred publication reports analysis of secondary data from 35 case studies [6].

With regards to the lack of case study based information and analysis Poland this publication is be very probably the first based on real project analysis.

3. Barriers associated with BIM adoption

Building Information Modeling is an enhanced method of transferring information about a construction project. This exchange can occur between various disciplines and throughout the entirety of a project's lifecycle. With the building industry showing signs of fragmentation, barriers and issues arising when adopting new processes can be expected. Rapid and accurate identification of these potential issues is critical as it will enable project participants to take the appropriate steps necessary to mitigate them and ensure project success.

3.1. Interoperability

Information flow and exchange is crucial in construction projects. Traditionally it was done in the form of 2-D drawings and documentation. BIM is used not only as a design tool, but also as an interface for information exchange between different actors and phases of a project. The fragmented nature of the construction industry resulted in the need for varying design and construction management tools to be used by industry professionals. Each project participant prefers tools which are specialized and tailored to their individual roles. The development of BIM tools for specific solutions and professions has resulted in a series of programs that do not interface well with each other. This led to the introduction of the Industry Foundation Classes (IFC), an open source international standard, developed by the "buildingSMART alliance". IFC is an attempt to achieve model-based interoperability through an accepted standard and covers a wide range of modeling information, not limited by the geometry of the objects, but also metadata related to other aspects of the building [25]. "Many software translators are not designed for multiple exchanges, and work only in one specified 'direction'. The software may convert the model well and export it, but then could return with corrupted files by merging the model back to its repository." [12] The industry is still currently developing and optimizing interoperability standards. BuildingSMART is constantly improving interoperability standardization while software vendors try to catch up with these developments in order to become IFC-certified. A key to improving interoperability in the industry is for software vendors to actively participate in the further development of interoperability standards.

3.2. Matching the user's requirements

The expectation of BIM's use on a project varies depending on both the project participant's role and the size of their company. Design firms expect BIM to be a further development and enhancement of 2D CAD. Constructors, on the other hand, see BIM as a tool which facilitates easier document and information management. The larger the firm, the more flexibility they want from the software, to be able to take on larger and more complex projects. This variance in expectations from BIM tools is most likely a result of the lack of consensus regarding what BIM actually is. Most industry professionals agree that BIM is composed of information rich 3D models, however the exact ways in which BIM affects work processes is vague. BIM's transfer of information can be used by project participants across all disciplines throughout the entirety of a buildings lifecycle. It is important to note that in a project, BIM itself is not the goal, but rather a means by which project goals may be achieved. Project teams needs to generate a BIM Project

Execution Plan at an early stage in the project. This will enable them to identify all of the potential ways in which BIM can be used to meet the project goals. Once project goals are clearly identified all major project participants must agree on developing information exchanges throughout the duration of the project. A comprehensive and well thought out BIM Project Execution Plan is a major key to ensuring that all project participants are "on the same page" and working collaboratively to meet the project requirements. Further development in workflow interoperability will also help bridge the gap in BIM use expectations amongst users from varying disciplines.

3.3. Changing work processes

Building Information Modeling is a much more collaborative approach to design, procurement, construction, and facility management. This approach requires that project owners, contractors, end-users, and facility managers be incorporated into the design process in an active way. They need to be able to insert, extract, update, or modify information within the building model throughout the duration of the project. With so many actors simultaneously having direct access to the project design, there needs to be a method of effective management of their activity. To assist in this web based multi-discipline collaboration platforms are necessary. There are many vendors offering these solutions such as: ConjectPM, ThinkProject, Trimble Connect, A360, etc. These products allow users to track changes and ensure that everyone is working on current and updated documents. Additionally project participants can quickly and easily communicate with one another, eliminating the need for paper based RFI's. Most importantly the platform serves as a data repository where all project information can be stored securely and in a standardized manner.

3.4. Legal issues

Since BIM considerably changes the way in which project participants work, there is potential for legal issues to arise. Often various designers do not work on a single model, instead they work on their own individual models and then integrate them. In theory the translation of data ought to be seamless, however this isn't always the case. The majority of software is capable of translating data from the model into a standardized IFC format. Unfortunately this process cannot operate reliably in a "round trip" fashion. This means that it is difficult to translate data from one system, transfer it to another, work on that data, and finally send it back to the original platform without any loss in data. If these errors lead to economic loss, issues regarding the liability for the loss arise. Additionally intellectual property, ownership of the model, and the information within the model must also be considered. Designers will also have more problems with receiving additional compensation for the possible efficiency savings associated with BIM [27].

To deal with the various legal challenges posed by the collaborative nature of BIM, it is necessary to adopt standardized contract documents which have been created with BIM in mind. The ConsensusDocs Coalition is a group of more than 40 leading design and construction industry associations who jointly developed ConsensusDocs. ConsensusDocs publishes a comprehensive catalog of legal documents to aid in forming of a legal framework between all parties involved in a project. ConsensusDocs 301 BIM Addendum was the first standard-form document ever to comprehensively address BIM. Legal documents drafted by ConsensusDocs were achieved thanks to the input from various parties such as: designers, owners, suppliers, contractors, insurers, NBIMS, and construction lawyers. Standard legal documents have difficulty addressing intellectual property rights issues while maintaining collaboration amongst disciplines. "Under the framework set forth in the BIM Addendum, a license to reproduce, distribute, display or otherwise use a party's model for the only purposes of the project is granted upstream and downstream to all parties working on the project. Also, the BIM Addendum is the first standard-form document to recognize that someone other than the design professional, such as the contractor or subcontractor, may have intellectual property rights in the project" [2].

3.5. Training and creation of new roles and responsibilities

BIM technology will not in itself enhance the construction process, but rather, it will enable a much more efficient and collaborative designing process. It is necessary that all project participants understand the purposes of each BIM use in the project. The success of the project is more dependent on the weakest contributor than the strongest. The training of all involved parties in the use of BIM tools becomes crucial to project success. Additionally the understanding of BIM's goals and uses in the project needs to be determined effectively very early on by individuals holding high positions in the project. This comprehensive understanding will then "trickle down" to the other project team members. In order to ensure that adequate BIM uses are chosen for each project goal there is a necessity for a BIM manager. The BIM manager would be responsible for coordinating all of the workflow between disciplines and would run collision checks. A BIM manager is directly responsible for ensuring that the BIM implementation into the project is done in accordance with the BIM Project Execution Plan.

4. Return on Investment

On March 1, 2016 during an interview with Graph'it CEO, Paweł Wierzowiecki, and Anna Anger, Business Development Manager, a comprehensive set of data reflecting the adoption of BIM technology into the Malta House project in Poznań has been attained. Graph'it Studio was a spin off from the Wierzowiecki Group. In the 15th year of its design activity the Wierzowiecki Group designed and modeled MEP installations for first building in Poland completely using BIM technology: "Malta House". The company now advises on BIM implementation to Government agencies, local authorities, Government-regulated industries and private sector clients to provide innovative, sustainable and economic solutions across a wide spectrum of business activities." [13]

Data regarding the economic impact of adopting BIM for Graph'it Studio has been collected and analyzed. The data included factors such as: amounts of various staff, salaries of various staff, costs of employee training, amounts of various types of workstations, cost of various types of workstations, maintenance costs, and income. The net revenue for each specific year (prior to and post BIM implementation) was calculated by subtracting the total annual costs from the annual income. By comparing the net revenue for each year to the base year, it is possible to monitor the changes in cash flow throughout the years. This is critical when trying to determine when the decision to implement BIM becomes profitable.

The results from the calculations showed that during the first year after BIM adoption the net revenue in relation to the base year was -507,000 PLN. After the second year the net revenue was -816,000 PLN in relation to the base year. After the third year the net revenue was -1,101,000 PLN in relation to the base year. One may draw the conclusion that the adoption of BIM into the "Malta House" project by Graph'it Studio showed to not be profitable. But does this mean that the adoption of BIM technology is not a good investment? To answer this question it is important to take a closer look at the conditions surrounding this case study. The "Malta House" project was the first project in Poland where BIM was used on a broad scale. Although it was not possible to attain economic value data regarding this project from Skanska (general contractor), it has been stated by multiple representatives of Skanska that the project was successful. In this project Graph'it Studio was responsible for the design of MEP installations using BIM tools. This was also the first project for Graph'it Studio where they implemented and used BIM tools. Once all of this information is put into perspective, the negative ROI for BIM implementation by Graph'it Studio starts to make sense. The majority of earnings resulting from BIM come from sources such as: energy efficiency analysis, facility maintenance, reduction in rework and RFI's, and clash detection. These benefits are, for the most part, reaped by the owner and contractor. Meanwhile the designers are expected to invest heavily in adoption of new technology and training their staff to operate that technology efficiently. In addition to this, according to the MacLeamy curve, the majority of the workload and effort is shifted towards the design phase. In order to make implementation of BIM more sustainable, "the design team must receive an increased fee for their extra effort and their openness in delivering quality design in the format of transferable digital information." [15] After the "Malta House" project Graph'it Studio is currently providing design solutions entirely using BIM for clients around the world with design offices in Poland, the United Kingdom, and the United States. The experience with the "Malta House" project allowed the company to better understand BIM from an economic point of view and to adjust their design fees to make BIM use sustainable.

Table 1. BIM Implementation Cash-Flow for the "Malta House" Project.

	Year 0 *(Prior to BIM Implementation)*	**Year 1**	**Year 2**	**Year 3**
Employee Allocation				
Number of Architects	5	5	2	2
Number of MEP Engineers	8	7	3	3
Number of Structural Engineers	4	4	1	1
Number of Quantity Surveyors	2	2	0	0
Number of Project Managers	3	3	3	2
Workstations				
Workstations – Normal/Old	22	3	0	0
Workstations – 3D BIM Capable	0	19	13	8
Staff Training Costs				
Annual Cost of Employee Training	- PLN	200,000.00 PLN	- PLN	- PLN
Operating Costs				
Average Annual Architect Salary	75,000.00 PLN	80,000.00 PLN	90,000.00 PLN	95,000.00 PLN
Average Annual MEP Engineer Salary	65,000.00 PLN	75,000.00 PLN	80,000.00 PLN	85,000.00 PLN
Average Annual Structural Engineer Salary	65,000.00 PLN	75,000.00 PLN	80,000.00 PLN	85,000.00 PLN
Average Annual Quantity Surveyor's Salary	50,000.00 PLN	60,000.00 PLN	60,000.00 PLN	60,000.00 PLN
Average Annual Project Manager's Salary	100,000.00 PLN	105,000.00 PLN	110,000.00 PLN	115,000.00 PLN
Annual Cost of Newly Procured BIM Workstations	- PLN	50,000.00 PLN	- PLN	- PLN

Annual Maintenance Cost of Normal Workstations	7,000.00 PLN	7,000.00 PLN	7,000.00 PLN	7,000.00 PLN
Annual Maintenance Cost Of BIM Workstations	- PLN	15,000.00 PLN	15,000.00 PLN	25,000.00 PLN
Income				
Annual Income	2,000,000.00 PLN	2,000,000.00 PLN	500,000.00 PLN	150,000.00 PLN
Total Cash Flow				
Net Revenue/Losses	291,000.00 PLN	- 216,000.00 PLN	- 525,000.00 PLN	- 810,000.00 PLN
Change from Base Year	- PLN	- 507,000.00 PLN	- 816,000.00 PLN	- 1,101,000.00 PLN

5. How should BIM adoption be driven?

The adoption process of any new technology or idea is never instantaneous throughout society. Instead, it is dependent on the individuals which are more apt to adopt a new innovation. In 1962 E.M. Rogers developed the theory of diffusion of innovation which not only demonstrates this fact but also shows that the people who are more willing to adopt new innovations have different characteristics when compared to those who adopt innovation later.

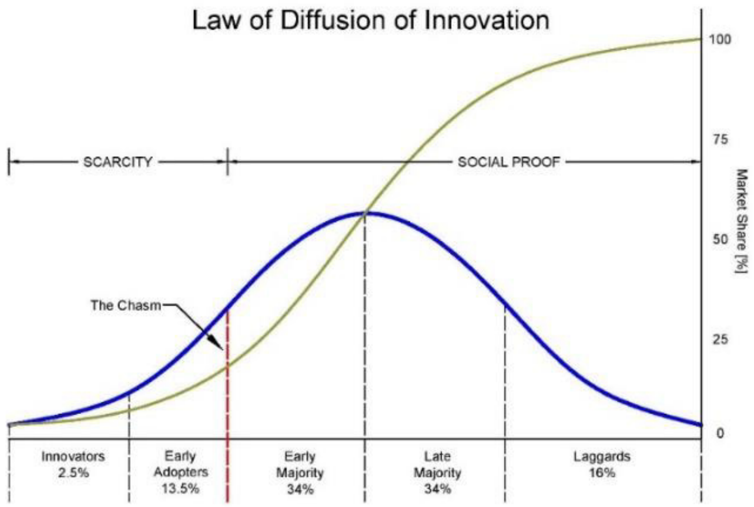

Fig. 1. Rogers' Law of Diffusion of Innovation [8].

There are five established adopter categories: [8]

- **A. Innovators** - These are the people who want to be the first to try the innovation. They are venturesome and interested in new ideas. These people are very willing to take risks, and are often the first to develop new ideas. Very little, if anything, needs to be done to appeal to this population.
- **B. Early Adopters** – These are people who represent opinion leaders. They enjoy leadership roles, and embrace change opportunities. They are already aware of the need to change and so are very comfortable adopting new ideas. Strategies to appeal to this population include how-to manuals and information sheets on implementation. They do not need information to convince them to change.
- **C. Early Majority** – These people are rarely leaders, but they do adopt new ideas before the average person. That said, they typically need to see evidence that the innovation works before they are willing to adopt it. Strategies to appeal to this population include success stories and evidence of the innovation's effectiveness.

D. Late Majority – These people are skeptical of change, and will only adopt an innovation after it has been tried by the majority. Strategies to appeal to this population include information on how many other people have tried the innovation and have adopted it successfully.

E. Laggards – These people are bound by tradition and very conservative. They are very skeptical of change and are the hardest group to bring on board. Strategies to appeal to this population include statistics, fear appeals, and pressure from people in the other adopter groups.

The Chasm - Occurs at the transition between the early adopters and the early majority. “Once you have reached 16% adoption of any innovation, you must change your messaging and media strategy from one based on scarcity, to one based on social proof, in order to accelerate through the chasm to the tipping point.” [18] The tipping point is the point at which the mainstream begins to adopt the innovation and sales begin to drastically increase. The scarcity approach is most effective on innovators and early adopters because they are interested in ideas others can’t have or do not know about. The early and late majority as well as the laggards are more interested in the social proof approach. It is also important to note that “early adopters have a vested interest in the early majority not adopting the innovation because it takes away from their scarcity needs.” [18] This is why it is important to target the appropriate audience with the right marketing scheme at the right time, as well as to change the approach once the chasm is reached.

Various governments throughout the world have adopted strategies aimed at increasing local BIM take-up in the industry. This often revolves around adopting BIM at a certain level (level 2 or level 3) within a specified time frame (typically five years). As an example the UK government adopted a “Push - Pull” strategy. The government “pulls” the industry towards BIM adoption by requiring that all public projects be delivered through BIM, enabling access to the design, costs, carbon, and performance of the asset throughout its lifecycle. The “push” element, on the other hand, is expected to be carried out by the industry. The industry is to be responsible for adoption and utilization of BIM by providing standardization, information, training, development, and infrastructure. This leaves the free market to be able to determine BIM best practices and have the freedom to constantly develop new solutions [5].

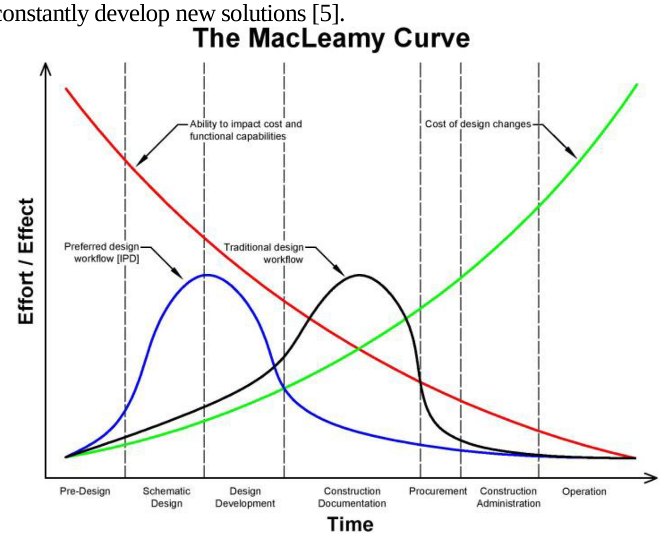

Fig. 2. The MacLeamy Curve [9].

The government driven approach has been shown to be quite effective in driving early adoption, more needs to be done to encourage private sector investors to drive widespread BIM adoption throughout the industry. According to MacLeamy the greatest economic potential is associated with the operation and facility management phase. There is a multitude of various areas from which facility managers can derive benefits from the BIM model. They include space management, building systems, equipment maintenance, energy consumption monitoring, security, fit-out, etc.

6. Conclusion

Currently the AEC industry throughout the world is attempting to adopt BIM as the future standard for building design, construction, and operation. However the adoption rates of this technology have been lower than expected. Various barriers impeding implementation have been identified and addressed. It is important to note that no one single barrier is solely responsible for hampering BIM adoption. Instead, the potential for these barriers to be able to impact adoption is project specific and varies from project to project.

The Return on Investment analysis also showed that design fees will most likely increase for companies working with BIM. This is a result of the greater workload occurring during the earlier phases of a project designed using collaborative tools. The owner can potentially gain the most from deciding to implement BIM into a project and therefore they should be encouraged to implement it. In many countries local governments are committing to BIM by requiring that all new public projects be completed using BIM at a specified level. When project owners understand the benefits of BIM-based facility management they will ensure that BIM is implemented to its fullest potential from the earliest phases of the project.

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