# Managing expectations of BIM product quality: a ‘lemon market’ theory view

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## Abstract

There is an increasing uptake of Building Information Modelling (BIM) in the architecture, engineering, and construction industry. At the same time, it is evident that many firms struggle to work based on the new technology and that only few highly IT-literate firms succeed in reaping BIM’s benefits. Thus, for many firms, BIM systems adoption ends in disillusion as to what can be achieved by using the technology. What complicates matters is that BIM’s are only found dysfunctional after having been in organizational use. Thus, BIM’s value for an organization is hard to distinguish before purchase. This article proposes, based on Akerlof’s (1970) theory of the “lemon market”, a conceptual model explicating factors affecting buyers’ initial quality expectations in BIM software purchase. Our findings are derived from data on a construction project executed by a Norwegian timber-frame construction company having heavily invested in computer numerical controlled (CNC) production machinery and BIM systems. This work is important to manage organizational expectations related to the initial adoption of BIM. Moreover, it highlights that construction firms’ trust in vendors claimed product quality, IT-literacy, and experience matter when purchasing BIM software. Taken together, our results suggest that quality uncertainty related to BIM purchase can lead companies into financial turmoil. Especially small and medium sized contractors appear to be exposed to information asymmetry when purchasing BIM software.
*Keywords: decision making, lemon market theory, BIM, software purchase, information asymmetry.*

WIT Transactions on The Built Environment, Vol 149, © 2015 WIT Press
www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/BIM150221

# 1 Introduction

In recent decades, Building Information Modelling (BIM) has been one of the major topics in architecture, engineering, and construction (AEC) research [1, 2]. In case studies of BIM use, scholars find BIM to be an effective tool for improving project delivery [3, 4]. Project level implementation of BIM appears to be positively influencing project cost, time, communication, and built quality [3]. However, research indicates that reaping BIM's benefits is not easy to achieve and that many firms miss out on the advantages BIM has to offer [2, 5].

This is partly due to BIM solutions not living up to the industry's vision of their use as inter-organizational collaborative tools [6], and issues related to the new ways of organizing required to create interoperable processes of information exchange and storage [7]. In addition, high investment costs are associated with BIM purchase and deployment [8]. The high upfront investments, in conjunction with firms not being able to use BIM to its fullest, frequently result in frustrations [9].

Thus, for many firms, BIM systems adoption ends in disillusionment as to what can be achieved by using the technology. Moreover, BIM's benefits become only tangible once firms "pass through the wilderness of adoption" [10]. This implies that BIMs are only found dysfunctional after organizations have spent considerable resources on system adoption and implementation. While few cases of actual BIM system 'retirements' or even 'bankruptcies' are reported in literature, we find plenty accounts on limited organizational use and value of BIM [11, 12].

Buying BIM software is often a matter of 'trust' as opposed to a well informed decision. BIM's value for an organization is hard to distinguish before purchase. Consequently, marketing and selling of BIM products should be supported by rigorous cost/benefit analysis justifying upfront investment [3]. The BIM software market is characterized by informational gaps between buyers (AEC firms) and sellers (software vendors). Imperfect information distribution between sellers and buyers, which is the case in BIM, is widely referred to as information asymmetry [13]. The term "lemon market" has been coined to refer to such markets [13]. A 'lemon' is an informal term used referring to a car that is found to be defective only after it has been bought.

Following up on the call to undertake more fine grained analysis of the use of BIM by Bryde *et al.* [3], we conduct a study inquiring into the mismatch between initial user expectations and the actual performance of BIM products. The research question asked in this article is:

*What factors affect quality expectations in BIM software purchase and what are the implications of this?*

To answer this research question we ran a series of interviews in a construction project at largely executed by a timber-frame contractor having heavily invested in BIM technology and CNC (computer numerical controlled) fabrication machinery. Understanding how BIM based work functioned at project level, several project team members such as the architect, the consultants, and client were interviewed as well. Lemon market theory (LMT) guided our analysis.

Our findings show how the timber frame contractor struggled in achieving benefits from utilizing BIM. This work is important to manage organizational expectations related to the initial adoption of BIM. Moreover, construction firms' trust in vendor's alleged product quality, IT-literacy, experience, and awareness of their market environment have been identified as influential when purchasing BIM software. Taken together, our results suggest that quality uncertainty related to BIM purchase can be reduced by increasing the industry's IT-literacy, since informed buyers are better buyers.

The remainder of the article is structured as follows. The second section introduces the LMT perspective supporting our analysis. The third section introduces the residential construction project and the professionals interviewed. The fourth section presents the findings based on the concepts important in LMT. The fifth section proposes a conceptual framework and presents both, the practical and theoretical implications of the study. The sixth section presents the conclusions and implications of our work.

## 2 Theoretical lens

In 1970 George Akerlof published a groundbreaking paper entitled *The Market for Lemons: Quality Uncertainty and the Market Mechanism* addressing the consequences of information asymmetry [13]. Akerlof claimed that in markets where it is impossible to assess the quality of a product/service upfront, where, so to say, the seller of the product has more information than the buyer, the market will gradually deteriorate and maybe even eventually disappear altogether. The theory derived from this work is referred to as lemon market theory (LMT). While most LMT research has been undertaken in the used car market [14], it has been applied to the study of other markets. Examples include the area of information systems [15] where e-markets, e-commerce, and e-auctions have been studied [16–18]. Given that it has been used in the realm of information systems before, LMT was considered a good fit for our study.

The main concern of LMT is that the quality of a product is un-assessable beforehand, thus giving sellers' incentives to present their products/services as being of higher quality than they actually are. Akerlof coins the term 'cost of dishonesty' to refer to the costs and adverse effects endured by buyers due to information asymmetry and dishonesty. He argues that the cause of information asymmetry lies in imperfect information distribution between sellers and buyers. In this situation, the sellers have more information than the buyers about the true quality of the goods from the market as a whole and buyers are led to believe that all goods in the market have the same good average quality. This leads to better quality goods not being traded in the market because their value may not be obtained. Consequently both the average quality of goods and the size of the market tends to fall [19].

Here lemon market theory is operationalized for analysing an example of BIM software purchase. The BIM market is characterized by software vendors releasing myriads of new products while common file exchange standards still emerge. Moreover, any IT implementation process is more than a software purchase; it disrupts the usual way of getting things done [20]. Thus, it can be considered difficult for buyers to judge BIM quality beforehand. The main independent constructs of lemon market theory are:

- alleged product quality by selling party
- expected/perceived product quality by buying party
- actual quality of the product
- perceived cost of dishonesty

We apply the aforementioned four main concepts of LMT to the BIM context of purchase and deployment. Doing so enables us to explore whether information asymmetry between buyers (AEC firms) and sellers (software vendors) exists.

## 3 Method

A case study was performed to explore whether a lemon market in the conjunction with the use of BIM in the building industry exists. The study covers the construction of a residential project executed by a timber frame contractor. The setting of the case study was a wood-frame, multi-story, low energy housing development in the Bergen area of Norway. The project comprised the construction of three apartment buildings consisting of one hundred apartment units.

The buildings' design is characterized by an extensive use of furbished prefabricated elements (e.g. wall panels including installations and finishes). These elements were produced based on advanced computer numerical controlled (CNC) fabrication machinery and BIM systems. The concept of CNC involves automated milling tools such as drills and saws being controlled by programmed commands describing a series of movements and operations. The concept of BIM has been defined as "a digital representation of physical and functional characteristics of a facility" [21].

The contractor executing the job was founded in 2001. The contractor actively participated in national Norwegian as well as European research projects to improve performance in the wood-based building industry. Despite receiving much recognition in the form of awards for their innovative products and solutions, the company struggled and had to declare bankruptcy in the end of 2012. The case study and interviews presented in this article were performed just four month before the bankruptcy happened. This is why the analysis part of the paper focusses foremost the contractor's use of design and production systems.

The project case was carefully chosen based on three selection criteria: (1) the project participants should resemble a typical project constellation in the construction industry (e.g. client, architect, engineers and contractors); (2) the design stage had to be completed at the time of data collection; (3) BIM technology had to be deployed in construction design. The criteria were selected to be able to provide a holistic account of construction design activity, to understand the perspectives of the actors involved typically in such activity, and to place BIM, as technological artefact, at the core of our study. By choosing interviews as the means of data collection we aim to gain an understanding of the phenomena by asking those experiencing them. The data has been collected based on 10 semistructured interviews with design professionals. These design professionals all worked in the residential construction project. The interviews were conducted between September 2011 and May 2012. We presume that the case represents a typical situation in the construction industry with regards to the actors involved and their digital modelling practices. An overview of the interviewees' professions and their roles in the project can be found in table 1.

Table 1: Professions of the 10 informants interviewed.

| Person interviewed | Services provided |
|---|---|
| – Timber frame builders CEO<br>– Timber frame builders design manager<br>– Timber frame builders drafter<br>– Timber frame builders production manager<br>– Structural engineer for wooden structures | Design, production, and installation of all wooden components |
| – Engineering design manager (for HVAC, structural, electrical)<br>– Geotechnical engineer<br>– Fire protection engineer<br>– Architect | Architectural, structural, fire-protection, geo-technical and HVAC design |
| – Client representative (CEO) | Client |

## 4 Findings

The analysis part of the paper is structured as follows: first the claimed, expected/perceived and actual product quality of the BIM design system used to prepare the shop-drawings for the prefabricated wooden components used by the timber frame contractor are presented. Second, a presentation of the perceived cost of dishonesty viewed from the buyers' perspective is presented.

*Alleged product quality by selling party.* The software vendor, namely cadwork® Software GmbH, placed several product quality claims prominently on their web-site. First, it is claimed that the software would provide buyers with the possibility to seamlessly integrate design and production processes. Moreover, the software is described as having an easy-to-handle user interface: "Consistency from planning to production, flexibility and easy-to-handle user interface are features that have made cadwork stand out more than 20 years. Let us convince you." [22]. The vendor claims that once purchased the system would prove to be a solid investment: "Our clients are present in most European countries, the United States, Canada, Russia and other parts of the world. Our international presence and know-how guarantee for a solid investment" [22]. Moreover, the system is supposed to ensure worry- and hassle-free site-installation and production of timber elements: "Each client has different requirements, but all have the same goals: plan quickly, reliably, detailed, and efficiently and ensure a worry and hassle free production and installation on site" [22]. In addition, the vendor claimed that Building Information Modelling data could be used straightforwardly in production: "Send production data directly from your building information model (BIM) to the current machining centres and or assembly lines" [22].

*Expected/perceived product quality by buying party.* The founders of the wood-contracting company had prior experience from working in advanced oil and gas projects. They worked together in a company specialized on subsea pipe handling when they had the idea of starting up a small, but innovative wood-construction company. The idea was to create a similar production and design environment to what is the norm in advanced mechanical companies. Based on prior experience they decided to operate based on object based design systems similar to what is used in mechanical engineering. Moreover, they decided to equip their production hall with advanced, robotic CNC mills allowing for automated machining of wooden components. Thus, the initial expectation in the software purchased was, that once it had been installed the system would allow for a smooth operation and data flow throughout the company. Moreover, the technology was placed at the core of the business: "This company is based on technology, it's based on 3D models, that is the whole idea" (Timber frame builder, CEO). The CEO continued and stated that the initial idea was to reuse information from sales, to design, to production and assembly, and efficiently curb unnecessary rework. Or in the words of the CEO: "when we started using that program we had a lot of expectations…". Thus, the initial expectations by the buyer were in line with what has been the alleged product quality by the seller.

*Actual quality of the product.* The wood contractors did not find the quality of the product to be standing up to the initial claims by the seller: "You don't get the benefits that are supposed to be there" (CEO). The product left the buyers with "lots of good and bad experiences and frustrations and some hope for the future" (Timber frame builder, design manager). While the system was generally considered to be technically sufficient for design and production of timber frames, the firm noticed that they were unable to effectively reap the benefits of BIM. To illustrate this, the timber frame designer stated that "the software has not been updated for some time and people struggle using it".

Moreover, the software used by the contractor did not allow for the expected reuse of data throughout the supply chain from sales, to design, to production and assembly. The CEO stated that information exchange in projects was not significantly improved by BIM deployment but rather resembled the traditional information exchange or the "same old thing" as he put it. The information exchange with other project partners usually did not work sufficiently well: "Now it feels like it always has been, that somebody might have different models and might have been working on the façade of the building, and they are doing that in SketchUp because that is easier for this, or they write something in a pdf and send that over, and then he is doing these changes to the model and then it comes back, and it's not working." (Timber frame contractor, CEO).

One reason for BIM not living up to initial expectations of improved information exchange was the limited interoperability of the contractor's design system with other systems used by project partners upstream in the supply chain (e.g. architects, consultants). The following quote illustrates this: "cadwork is a small margined software from Germany, maybe it's big down there but if I ask somebody [in Norway] about 'are you familiar with cadwork?' nobody is. […] most people have heard about Revit and nobody heard about cadwork. It's like the video tapes in the eighties – beta and VHS and Phillips – and everybody knows that beta was the best quality, Phillips was the best technology but VHS was the best known system like Autocad". How project partners where unfamiliar with the design system used by the timber frame company follows from the statement made by the engineering design coordinator: "I knew what the architects use and I know what we use, but what the timber frame contractor uses, I haven't got a clue".

*Perceived cost of dishonesty.* The timber frame firm's main focus was: "to build small residential construction projects" (Timber frame builder, CEO). "However, we see that no matter how hard we try pressing the price if we design a good house based on BIM, we always lose to the competition" (Timber frame builder, CEO). Thus, the company perceived that it was difficult to compete by using BIM and advanced CNC machinery in the Norwegian market for small family homes. They were repeatedly outcompeted by competition relying on on-site production and not using advanced technologies. This is illustrated by the following quote: "they [other contractors] have their car and some tools and just do all the work on site, the buildings are getting wet, they do not document anything" (Timber frame builder, design manager) leaving the timber frame contractor's CEO repeatedly asking and answering the following question: "How can we compete with these companies? It is impossible".

Consequently, the timber frame contractors board of directors decided to gradually retire the system and replace it by a more widely known and used system, namely Revit®. The company had purchased two Revit licenses and had begun training several employees in using the software. This was done because the CEO wanted to "cut down on some of the tedious work and make the design programs easier to use". Moreover, the CEO pointed out that the company was in a state of financial hardship which can partially be attributed to BIM deployment. The following statement by the CEO confirms this observation: "We have problems, we have a lack of money and a lack of sales, and we are struggling to survive!" The CEO continued to state that the high fluctuation of employees in small contracting firms posed challenges especially considering the staff training required for operating advanced design and production systems like BIM. Moreover, he pointed out that appropriate communication and information exchange is a major challenge when seeking to work profitably based on BIM. As of August 2012, shortly after the interviews presented here were held, the timber frame contractor filed for bankruptcy.

## 5 Discussion

The research question asked at outset of this article was: *What factors affect quality expectations in BIM software purchase and what are the implications of this?* The main constructs of lemon market theory, introduced in section two, were used to structure the findings. Below the findings are briefly discussed, before a conceptual model elaborating the factors found influential in BIM quality expectations are presented.

From the findings of the case it follows that the timber frame contractors adopted a business strategy entirely focused on 3D modeling and object based design. This signifies that *initial product quality expectations* by the buyer were relatively high. Choosing a so-called ‘big bang’ adoption can be viewed as a risky strategy for a contractor, since organizational effects of IT are difficult to foresee due to “computing infrastructure, the interplay of conflicting objectives and preferences, and choice processes” [23]. Moreover, the temporary nature of construction projects where “nobody feels responsible for long term investments in ICT facilitating what is best for the project” hinders the use of advanced systems such as BIM [24]. What complicates matters is that newly adopted systems may become obsolete for the next project because there will be a “new constellation of actors with (maybe) new versions of ICT applications” [24].

The BIM vendor’s *alleged product quality* contributed to raising high initial quality expectations. The claims of BIM being a solid investment allowing for seamless integration of design, construction, and manufacturing were trusted by the buyer. Arguably, the buyer’s trust in product quality resulted from not having prior experience from working based on digital design systems in the construction industry. The contractor was not in a position to foresee the challenges emerging in BIM-based design and construction work. This indicates that the contractor’s decision to adopt BIM was subject to quality uncertainty and largely a matter of trust. Trusting vendors’ product quality claims has been identified as a core driver for purchasing decisions in ‘lemon markets’ [19].

The identified *perceived actual quality* of the product indicates that BIM in this case turned out to be a ‘lemon’ similar to what has been argued by Akerlof. This is signified by the *perceived costs of dishonesty* incurred by the contractor, namely: BIM and the advanced production machinery failing to deliver expected benefits. Moreover, choosing such advanced design and production methods proved to be challenging in the context of the Norwegian family home market. According to the contractor, having a business model focused on advanced design technology proved dysfunctional. Based on this, the claim by the vendor that BIM would be a guaranteed solid investment can be rejected for this context.

## 5.1 Contributions to research

Apart from presenting an early application of ‘lemon market’ theory to the context of BIM purchase in the architecture, engineering, and construction industry we contribute a conceptual model derived from the findings of the present case study (see figure 1). First, as argued above, it can be claimed that the contractor trusted the acclaimed product quality by the seller. Second, the contractor had neither construction experience nor BIM experience. We argue that the combination of the aforementioned resulted in distorted product quality expectations by the buyer. Managing or reducing quality uncertainty would require buyers to obtain an ability to make informed decisions. Based on our findings we argue that trust in BIM vendors, BIM experience, and construction experience are all influential for reducing quality uncertainty and for arriving at realistic BIM product quality expectations.

The conceptual model presented in figure 1 can be seen as a post hoc rationalization derived from a single case study. While we claim that the present case represents a typical project in the construction industry, further work should put the suggested model to a test in other project settings. While we argue the three factors, namely: trust, BIM-, and construction-experience, were influential for initial BIM quality expectations in this case project, there may be other factors at play which lay beyond the scope of our study. In addition, further research should validate the relational links depicted in our initial model, namely: (H1) High trust in BIM vendor increases inaccurate product quality expectations; (H2) High BIM experience decreases inaccurate product quality expectations; and (H3) High construction experience decreases inaccurate product quality expectations.

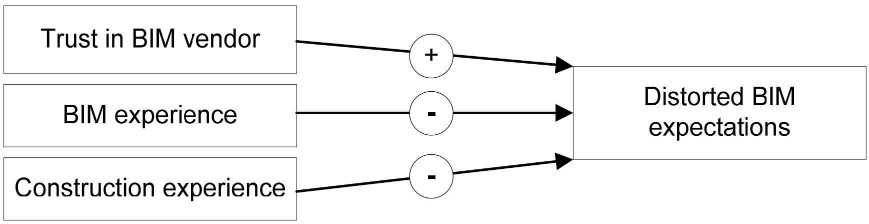


Figure 1: Factors affecting BIM product quality expectations.

Further research should go beyond identifying factors preceding buyers' distorted BIM expectations and also explore the organizational implications of these. Our study opens up for several intriguing research avenues. First, there appears a need for inquiries into BIM system retirements where one system is replaced by another or BIM is abandoned altogether. Second, is BIM system retirement a wide spread phenomenon in the industry? Third, is small and medium sized construction firms' exposure to distorted BIM expectations and their ramifications higher than those of larger corporations?

## 5.2 Contributions to practice

The case has shown that BIM systems proved challenging for a contractor working in the Norwegian market for family homes. The challenge lay within competition from contractors working on a 'low tech' approach without using advanced systems. This indicates that BIM does not yield unconditional positive implications for all types of construction projects [12]. According to the contractor, residential homes in Norway can be built without creating much documentation. It appears that Norwegian municipalities should increase their control of construction documentation making BIM a more useful tool.

Contractors should also consider adopting systems widely used and known in the industry to reduce their exposure to interoperability issues. Last, implementing BIM throughout the entire company and all projects leaves contractors with a limited capability to respond to situations where project partners operate based on older technology.

For now, especially small and medium sized contractors executing simple and industry standard types of projects are well advised to carefully manage their expectations in what can be achieved by adopting BIM technology. The case presented here indicates that in cases where BIM turns out to be a 'lemon' and does not deliver expected results small companies can run into financial problems. Distorted BIM quality expectations can be mitigated for by adopting a critical view to vendor claims, prior experience from working based on BIM, and construction experience. A thinkable response to the information asymmetry involved in BIM software purchase could be the formation of industry BIM clusters where experiences made with different solutions could be shared.

## 6 Conclusion

Based on a 'lemon market' theory study of a case of a timber-frame construction company, this article has provided an initial conceptualization of the factors affecting BIM product quality expectations. Our analysis shows that (1) trust in BIM vendor; (2) BIM experience; and (3) construction experience are influential for initial expectations in BIM product quality. The work presented in this study is important to manage organizational expectations of what can be achieved by adopting BIM technology. The case further illustrated that BIM does not yield unconditionally positive implications for all types of construction projects. Moreover, BIM may turn out to be a 'lemon' not delivering the acclaimed and expected organizational results. Especially big bang adoptions of BIM in all projects appear risky and may lead companies into financial problems. Further research should continue exploring the factors important for managing organizational BIM quality expectations. Moreover, there is need for work exploring the organizational implications of distorted BIM quality expectations.

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