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# Life Cycle Costing Assessment: A Building Information Model (BIM) Investment Evaluation for General Contractors in the Construction Industry

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# Life Cycle Costing Assessment : A Building Information Modeling (BIM) Investment Evaluation for General Contractors in the Construction Industry

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# 1 Knowledge Management in the Construction Industry

In December 2012, the Journal of Management in Engineering called for papers for a special journal issue. The special journal was titled "Information and Communication Technologies (ICT) in AEC Organizations: Assessment of Impact on Work Practices, Project Deliver and Organizational Behavior." The special journal was looking for AEC industry research on the important topics of technology and information. As the movement of the information culture continues to become an increasingly important topic in the AEC industry, the costs and impacts associated with learning, managing and maintaining this informational knowledge will need to be evaluated and answered.

The term knowledge management (KM) refers to the organizational use of information that adds value through productivity increase (time and money savings) by way of (ICT) tools. The propose of this research project is to perform an Life Cycle Costing Assessment (LCCA) specifically evaluating the monetary inputs (costs) and outputs (potential savings) for a general contractor in the construction industry when investing in KM technology. The KM technology specifically being evaluated is Building Information Modeling (BIM).

**The Rise of BIM in the Construction Industry**

In the past few years the use BIM has become increasingly more common in the industry. The efficiencies of the tool (time, redundancies, and money) have been mentioned; however, the costs (time and money) of implementing such KM technology system needs to be further explored. This assessment will specifically identity and quantity the required software, hardware and training needed for BIM and potential financial savings from this investment.

# 2 System Boundary

## 2.1 Construction Project Stages

According the Construction Industry Institute (CII), there are six stages in the typical life cycle of a construction project. Figure 1 names these important stages. The life cycle of the project begins with the front end planning of the project. Typically the feasibility, concept and detailed scope stages are assessed when planning for a successful construction project [5]. In the front end planning phase, the important decision of a "go" or "no go" decision is made by the owner of the project. Afterwards the selection of the contractor is decided by the owner of the project.

The following the next two stages of a construction project (design and construction) heavily involves the contractor. The contractor is responsible for successfully building what has been designed. However, in recent years the contractor is becoming more involved in the design process. Mainly to assess the "constructibility" of proposed designs.The last two stages of a construction project involves the occupants of the finished building. The contractors in involvement with the project decreases.


Figure 1: Construction Project Stages

### 2.2 Assessment System Boundary

Based on the project stages in Figure 1, the system boundary of this LCCA will focus on the construction stage, specifically from the contractors perspective. In the construction Figure 2 is a visual representation of the system boundary and the progression of a construction project.

Before the reward of a project contract, the general contractor assesses and plans for the required resources to complete a project in the planning stage. The planning stage is a very important stage for the contractor. The site mobilization stage for a general contractor includes moving the required equipment, materials and labors to a job site. Once mobilized on the project site, the contractor can develop the construction site (land assessments and grading). Once completed the foundation is built, the outside of the building (envelope) is finished. Depending on the materials (concrete or steel) and the size of the project, the stage can be lengthy. The interior of a building includes, all the inside structural elements, fixtures and finishes. Finally, once the interior is completed, the general contractor closes out a project with the completion of a "punch" list of minor mainly cosmetic items.

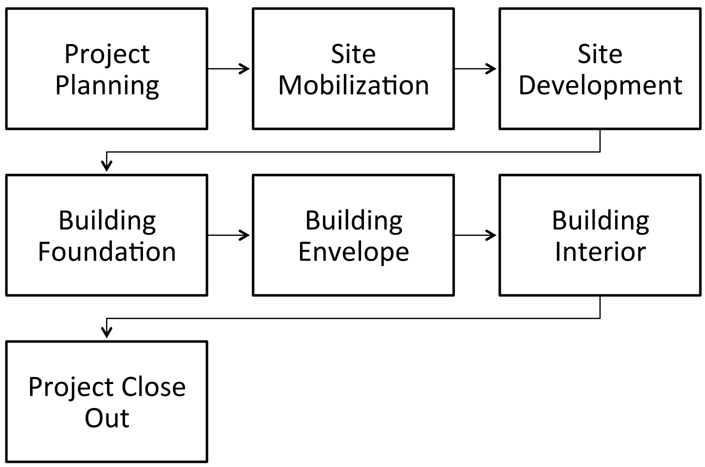


Figure 2: Assessment System Boundary

## 3 Methodology

In order to estimate and model the resource inflows and outflows in the construction stages, it was important to assess the research already completed on ICT and BIM in the construction industry. The following chapter exams the literature used to better understand KM and ICT in the construction industry. Also, the LCCA model created to calculate the potential economic profit/loss of investing a BIM is detailed.

### 3.1 Literature Review of Data Sources

The literature reviewed to better understand ICT and KM in the construction industry can be arranged into two categories. The first category pertains to the system definition and the identification of needed resources. Below are a summery of helpful resources.

1. **BIM Deployment: A Process to Adopt and Implement a Disruptive Technology**[3]
   In his thesis, Tim Hamilton outlines the important components of a BIM system in the AEC industry. This paper helped to identify participants in the BIM process. Also, the resource identified factors that influence ROI of this knowledge management system.

2. **An exploratory study of indirect ICT costs using the structured case method** [6] In this paper, the authors perform an exploratory study of indirect ICT costs specifically for a construction organization. The paper assessed indirect costs that were considered in the LCCA.

3. **Information communication technology (ICT) implementation constraints: A construction industry perspective** [7] The paper gives insight to the differences of a intranet system versus a organizational wide knowledge management system. This study helped clarify the differences between a centralized and non centralized KM system.

4. **End-user attitudes toward EDM use in construction project work: case study**[4]

5. **ICT implementation and evolution: case studies of intranets and extranets in UK construction enterprises**[11]

This second list pertains to the cost and time of the resources. These data sources were referenced to estimate LCA input and output results.

1. **A Costing Model for Project-Based Information and Communication Technology Systems** [10]
   This article is geared toward institutional ICT systems, it shares a solid method for identify costs within systems (it also lists cost associated with ICT systems). Stewart's paper was helpful for assessing cost estimates for ICT human resources.

2. **An evaluation model for ICT investments in construction projects**[1] This research presents a method to estimate the financial costs and benefits of an ICT system, specifically a Virtual Reality (VR) system.

   The following three sources were used to estimate costs and benefits of a KM system in the construction industry.

3. **ICT in the construction sector: Computing the economic benefits**[9]

4. **The innovation process: adoption of information and communication technology for the construction industry** [8]

5. **Evaluating IT investments in Construction**[2]

## 3.2 LCCA Scenario

The life cycle costing assessment (LCCA) deals with the initial investment and the impact of new technology to help construction companies with knowledge management for project management improvement The scenario for this assessment is that of a small construction general contractor. According to the Small Business Administration, the definition of a small commercial building contractor is one that with yearly revenues of $33.5 million or less. This life cycle costing assessment (LCCA) is relevant in assessing the value of a small contractor assessing the cost and savings investing in ICT to better manage project specific knowledge.

The initial investment for the small contractor is the purchase of building informational modeling (BIM) software system and the technology to make the system run effectively in both an office and project site environment.

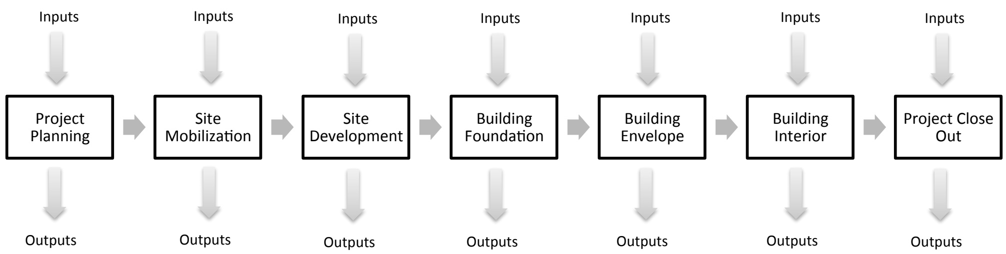


Figure 3: Input and Output for Construction Stages

## 3.3 LCCA Model

The assessment model is two part in nature. First, there is the initial ICT investment or cost of the BIM and the necessary technology. Secondly, there is the total savings from the investment of over time. The calculation of the initial ICT investment is relatively straightforward. The initial cost includes the BIM softwares, additional office computer technology, maintenance of the system.

The total savings for the model is more complex in nature. First a construction project needs to be estimated. Depending on the location of the project the price varies. For this assessment the contractor is hired to build a commercial building for $3.0 million. The overall project for the contractor is five percent (in line with the typical low profit margins in the industry). This means that the contractor will have a dollar cost, or inputs (see Figure 3), of $2.85 million. This cost is allocated to the seven different stages of construction.

### 3.3.1 Net Present Value (NPV)

Once the cost input number for each stage is calculated the savings percentage from the BIM investment is applied. The economic calculation to evaluate cost savings is called the net present value (NPV) method. In short, NPV calculation sums the initial investment of a project (negative cash flow) and the potential future savings (positive cash flows). A very important step in the NPV method is discounting future flows to the present. In order to accomplish this a rate of return is needed (the six month US Treasury Bond Rate is used). An equation of the NPV method is given; this is the foundation of the model.

$$\text{NPV} = \text{-Initial ICT Costs} + \text{Future Savings (Discounted to Present Value)}$$

# 4 Inventory Analysis

## 4.1 Life Cycle Costing Results

The results of the LCCA are presented in tables 1 and 2. Once again the results are for a general contractor with a $3 million project contract with 15 month construction time schedule. Table 1 shows the (1) BIM Investment, (2) cost allocation and (3) potential future savings of 1.5 percent. Looking at the results in tables 1 and 2 it can be seen that the BIM investment for a general contractor is roughly $32 thousand. The construction cost for the contractor of $2.85 million is allocated to the seven stages. For example, the project planning is 10 percent of the total construction cost, which is a total of $285 thousand. The building interior stage has the highest cost allocation percentage at 35. This percent accounts for $997 thousand.

According to Table 1, the total BIM investment is roughly $58 thousand. This includes the cost for the BIM software along with hardware (server, computers, and portable devices) and the training. The annual cost of the BIM software is used for the investment cost. However, this is a recurring cost that should be analyzed yearly for a general contractor. The cost of a server and additional storage of digital storage is also included. Fifteen portable devices account for the $10 thousand investment. For training, a team of three at an hourly rate of $35 per hour with three months of training was assumed.

The total cost of construction is estimated at 95 percent of the contract price or $2.85 million. The construction cost is allocated to the seven stages of construction based on the percentage of cost each stage would normally cost. For instance, project planning for a general contractor is 10 percent of the total cost of a project. Ten percent of the $2.85 million equates to $285 thousand for project planning stage. This calculation method was used for the remaining construction stages.

To determine the potential savings for the project from investing in BIM, the saving percent of 1.5 is applied to all seven construction stages. The total of $42,750 is the non discounted potential savings of 1.5 percent. When this total cost savings is discounted to the present the total is $42,666.

| | | | | |
|---|---|---|---|---|
| **Project Information (Assumptions)** | | | | |
| **Contract Size** | | $ 3,000,000 | | |
| **Time of Project (Months) (Bid to Occupancy)** | | 15 | | |
| **Time to Implement BIM** | | 5 | | |
| **Construction Profit** | 5% | $ 150,000 | | |
| **Construction Cost** | 95% | $ 2,850,000 | | |
| **Treasury Six Month Rate (Discount Rate)** | 0.1% | | | |
| **Potential BIM Investment Savings** | 1.50% | | | |
| **1. BIM Investment** | | | | |
| BIM Software (Annual License) | | $ 16,485 | | |
| Server & Storage | | $ 7,000 | | |
| Office Computers | | 5,250 | | |
| Portable Devices (Tablets for PM/Field) | | 10,500 | | |
| Training (Design/Estimating Group) (15hrs/week for ea. 3 months training) | | 18,900 | | |
| | | $ 58,135 | | |
| **2. Construction Stage Cost Allocation** | | | **3. Construction Stage Savings Allocation** | |
| Project Planning | 10% | $ 285,000 | 1.50% | $ 4,275 |
| Site Mobilization | 5% | 142,500 | 1.50% | $ 2,138 |
| Site Development | 10% | 285,000 | 1.50% | $ 4,275 |
| Building Foundation | 15% | 427,500 | 1.50% | $ 6,413 |
| Building Envelope | 15% | 427,500 | 1.50% | $ 6,413 |
| Building Interior | 35% | 997,500 | 1.50% | $ 14,963 |
| Project Close Out | 10% | 285,000 | 1.50% | $ 4,275 |
| | 100% | $ 2,850,000 | | $ 42,750 |

Table 1: BIM Cost and Construction Cost Allocation

Table 2 shows the investment loss for a general contractor investing in BIM with a potential savings of 1.5

percent. When evaluating the total BIM investment of $58, 135 compared to the present value savings of 1.5 percent, $42,666, there is a lost of of $15,469. Therefore, a general contractor that invests in BIM expecting savings of 1.5 percent should not make the initial investment because the cost of the BIM exceeds the present value of the potential savings.

| **4. NPV Calculation** | | |
|---|---|---|
| **Time (Months from Present)** | | |
| 0 | Initial Investment | $ (58,135) |
| | | |
| 7 | Bid/Project Planning | $ 4,271 |
| 8 | Site Mobilization | 2,135 |
| 10 | Site Development | 4,269 |
| 12 | Building Foundation | 6,402 |
| 15 | Building Envelope | 6,400 |
| 19 | Building Interior | 14,925 |
| 20 | Project Close Out | 4,264 |
| | | |
| | **Investment Profit (Loss)** | **$ (15,469)** |

Table 2: Investment Cost and Saving Cash Flows

## 4.2 Savings Scenarios

An important element of an assessment is the analysis of potential scenarios. For this LCC assessment, the savings rate for investing in a BIM is explored. The nature of construction are projects of high dollar amounts and low profits. If a BIM for a general contractor can potentially save an additional percent or two, there is a potential large saving potential for the contractor. Below in Table 3 three saving scenarios are presented along with the calculated profit and loss potential for investing in a BIM.

| | **Scenario A: 1.5% Savings** | **Scenario B: 2.0% Savings** | **Scenario C: 2.5% Savings** |
|---|---|---|---|
| Initial Investment | $ (58,135) | $ (58,135) | $ (58,135) |
| | | | |
| Bid/Project Planning | $ 4,271 | $ 5,695 | $ 7,118 |
| Site Mobilization | 2,135 | 2,847 | 3,559 |
| Site Development | 4,269 | 5,692 | 7,116 |
| Building Foundation | 6,402 | 8,536 | 10,670 |
| Building Envelope | 6,400 | 8,533 | 10,666 |
| Building Interior | 14,925 | 19,900 | 24,874 |
| Project Close Out | 4,264 | 5,685 | 7,106 |
| | | | |
| **Investment Profit (Loss)** | **$ (15,469)** | **$ (1,247)** | **$ 12,975** |

Table 3: Investment Cost and Saving Cash Flows

According to Table 3 a BIM must provide more than two percent savings in order to considered a viable option. At a savings rate of 1.5 percent there is an investment loss of more than $15 thousand. At a 2 percent savings rate is small loss of $1 thousand. However, at a 2.5 percent saving rate there is a investment profit (return) of almost $ 13 thousand.

### 4.3 Data Uncertainty

The NPV and DCF methods used to create the assessment model has been proven through various economic and financial applications. Therefore theses methods are used with certainty. However, the areas of uncertainty for this assessment are the following:

1. **Discount Rate**
   Depending the financial standing of the commercial building contractor, the potential to earn a higher rate of return is a question. Also, there is an assumption investing in the BIM system is risk free.
2. **BIM System Cost**
   Depending on the type of software and system sophistication, the cost can vary greatly.
3. **Savings Percentage from BIM System**
   The model should evaluate savings based on the number of change orders that the system prevents. Currently, there is a blanket percentage that describes the savings from the BIM system.

The list mentioned above includes areas of data uncertainty. Sensitivity analysis was be performed on all three uncertainty factors. It was determine that the savings rate from the BIM investment was the most impactful in the results. Therefore three scenarios were given in the previous section to assess the profit/loss impact of the savings rate.

## 5 Conclusions

In the construction industry the management of knowledge is becoming an increasingly important element for success. The successful management of knowledge helps general contractors to better compete which ultimately leads to more contracts and potentially greater profits. The LCC assessment presented here, is a small step in understanding the complex decision of investing in BIM from general contractor's perspective. This assessment has identified the cost components for BIM and has allocated the cost for a typical project.

#### Limitations and Future Research

The profit/loss result of the NPV calculation is very sensitive to the savings percentage in the model. A major limitation of the study is the savings rate used in the LCCA. Since a savings rate could not be identified (through research) a range was given. If the true savings for general contractor associated with a BIM investment is less than two percent, there is no need for the investment. If the savings rate for investing in BIM is better understood, the construction industry could better evaluate this technology.

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