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Advantages and Disadvantages of BIM Platforms on Construction Site

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Aos meus pais e irmã

"Ou és diferente ou Invisível!"
Valete

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RESUMO

Building Information Modelling (BIM) é uma nova e promissora abordagem na industria da Construção, tendo vindo gradualmente a ganhar aceitação por Donos, Arquitectos, Engenheiros e Construtores, como um processo inovador de gerar, analisar e manter durante todo o ciclo de vida de um empreendimento a sua respectiva informação e *data*. Porem, BIM é uma tecnologia disruptiva imputando uma grande transformação na indústria da construção, como tal no que diz respeito ao deslocamento de métodos de trabalho tradicionais e mentalidades já bem estabelecidas representam grandes dificuldades e barreiras.

Atendendo á natureza disruptiva do BIM, uma parte deste trabalho fosse a problemática de implementar metodologias BIM numa empresa de construção civil (Construtora), providenciando *guide-lines* e recomendações, apresentando ao mesmo tempo algumas barreiras e dificuldades que se apresentam ao longo do percurso de implementar BIM. Devido á grande diversidade do tipo de empresas de construção e construtoras, é concluído neste trabalho que o processo de implementar BIM, é uma tarefa árdua porem recompensadora, onde para se alcançar mudanças em termos tecnológicos, políticos e organizacionais, é necessário um ainda maior esforço no sentido de modificar e adaptar a forma das pessoas trabalharem e lidarem com esta tecnologia.

Passando do escritório para o campo, directores de obra e pessoal de campo gasta uma parcela significativa de seu tempo em tarefas sem valor acrescentado, como a transcrição de notas, e em tarefas de valor acrescentado, mas ainda assim demoradas como a colecta de dados do projecto, avaliação das taxas de produção, comunicar-se com os participantes do projecto e o acompanhamento da qualidade do projecto. Aliando BIM com *Field Data Management Tools* (FDMTs), é possível melhorar a eficiência automatizando e reduzindo o tempo de tarefas de valor acrescentado e eliminando parte das tarefas de sem valor acrescentado da metodologia tradicional. Melhorando, ao mesmo tempo, a qualidade do produto final de construção, permitindo comunicações melhor, mais rápida e fiáveis da informação do projecto precisos.

Através do estudo do *software* BIM 360 Field da Autodesk, conclui-se que através de uma melhor organização, acessibilidade, mobilidade das informações sobre o projecto e seus usuários, o *software* representa um grande potencial de retorno do investimento, o que representa uma melhoria na eficácia da gestão, a eficiência do projecto, comunicação sobre o projecto entre todos os participantes, e produtividade das equipas.

ABSTRACT

Building Information Modelling (BIM) is a new and promising approach in the AEC industry, gradually gaining acceptance by Owners, Architects, Engineers, and Contractors, as an innovative process of generating, analysing and managing building data during its lifecycle. However, BIM is a disruptive technology inputting major transformations in the construction industry, therefore, are significant challenges regarding the displacement of well-established traditional working methods and mindset change in organization.

Accounting for the disruptive nature of BIM, part of this work focus on the issue of BIM implementation in construction companies (Contractors), providing guide-lines, recommendation and emphasising the difficulties and barriers of the implementation path. Because of the diversity of construction companies and the disruptive nature of BIM, it is concluded that the process of implementing BIM is a rewarding yet challenging task, where in order to easily achieve company's technology, policy and process change, a bigger effort should be put into modifying and adapting people's old mindset to BIM.

Passing from the office to the field, construction managers and field personnel spend a significant portion of their time on non-value adding activities, like transcribing records, and in value-adding but yet time consuming activities like gathering project data, assessing production rates, communicating with project participants and tracking project quality. By allying BIM to Field Data Management Tools (FDMTs), is possible to improve efficiency by automating and reducing the durations of value-adding task and eliminating some of the non-value-adding tasks of the traditional methodology. Improving at the same time, the quality of the final build product by enabling better, quicker and more reliable communications of accurate project data.

Through the study of BIM 360 Field software from Autodesk, is concluded that through the better organization, accessibility, mobility given to project information and its users, the software represents a potentially large return of investment, representing an improvement in management effectiveness, project efficiency, communication on the project between all participants, and staff productivity.

Keywords: Building Information Modelling (BIM), Implementation, Field, Construction Management, Field Data Management Tools (FDMTs)

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SYMBOLS AND ABBREVIATIONS

2D – Two Dimensions

3D – Three Dimensions

3DS – 3D Studio Extension File

4D – Four Dimensions, referring to Time

5D – Five Dimensions, referring to Cost

A – Architects

AEC – Architects, Engineers and Contractors

BBC – Balfour Beatty Construction

BDS – Building Description System

bim – Building information Model

BIM – Building Information Modelling

BP – Business Process

CAD – Computer Assisted Design

CII – Construction Industry Institute

CIS/2 - CIMSteel Integration Standards

CM – Change Management

CMM – Capability Maturity Model

CMR – Construction Management at Risk

CMU - Carnegie Mellon University

COBie – Construction Operations Building Information Exchange

COTS – Commercial Off-The-Shelf

DXF – Data eXchange Formats

E – Engineers

FDMTs – Field Data Management Tools

FM – Facility Management

GIS – Geographic Information Systems

GLIDE – Graphical Language for Interactive Design

HVAC – Heating, Ventilation, and Air Conditioning

IAI – International Alliance for Interoperability

IFC – Industry Foundation Class

ISO - International Organization for Standardization

IT – Information Technology

MGH – Maryland General Hospital

NBIMS – National Building Information Modelling Standard

NIBS - National Institute for Building Sciences

O- Owners

O&M – Operation and Maintenance

PDM – Project Data Management

QA/QC – Quality Assurance /Quality Control

RFIs – Radio Frequency Identification

ROI – Return of Investment

SaaS – Software as a Service

SAGE – System for Algebra and Geometry Experimentation

STL – Stereo-Lithography

UK – United Kingdom

US – United States

XML – eXetencible Markup Language

1
INTRODUCTION

1.1. MOTIVATION

Building Information Modelling (BIM) is an emerging technology throughout the world in the Architecture, Engineering, and Construction (AEC) industries. BIM technology provides users with accurate and consistent building/project data and information, accommodating the functions needed to model the building and provides a virtual view of it. Building information models are increasingly used, for several purposes by the diverse stakeholders during the different phases of the project and building lifecycle (Figure 1.1).

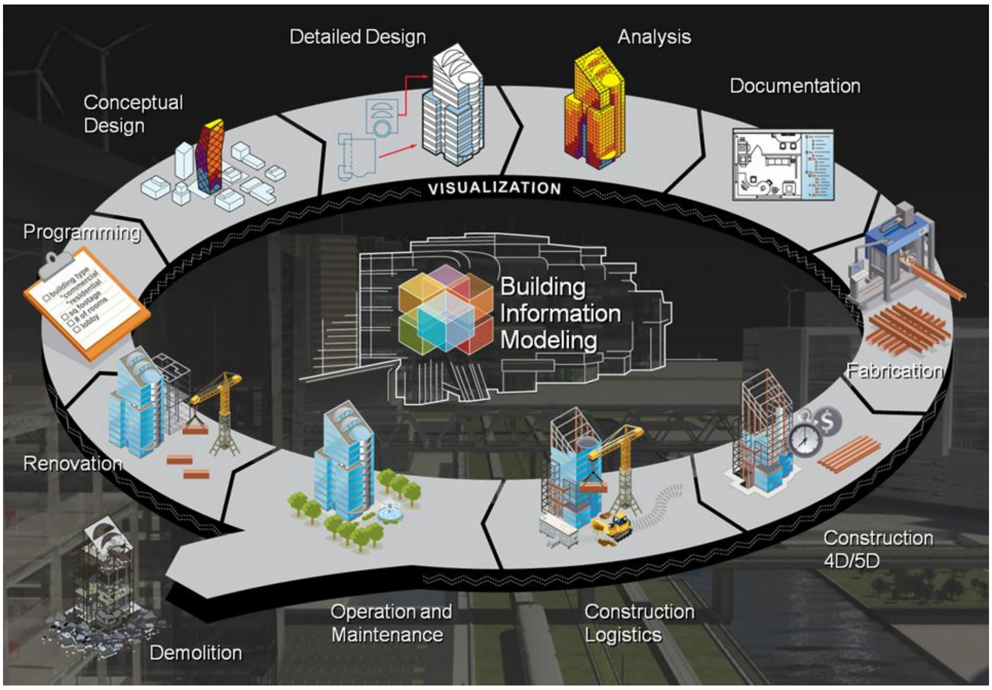

Figure 1.1 - BIM Life Cycle [1]

As world leaders in BIM adoption, integration, and use in the AEC industry, North-America alongside UK are examples to follow and learn from.

BIM revolutionize the AEC industry, being not only a change between CAD and parametric modelling with 3D capabilities, but a change of workflows, methodologies, process, and relations. Basically it changes the way business is done throughout the industry. Although all of these changes may seem too much to be easily accepted by the industry, the benefits are much greater, making BIM the future for the industry.

According to the 2012 McGraw Hill construction report "*The Business Value of BIM in North America*" [2], since 2008, industry wide BIM adoption as grown 43%. In 2012 71% of American architects, engineers, contractors, and owners, had already become engaged with BIM. Although BIM adoption, by contractors, as shown a significant growth (Figure 1.2), it reflects the increasing number of contractors that are engaging BIM in the preparation and monitoring of the construction activities, schedule and budget tracking, 4D and 5D BIM, virtual construction, and office activities.

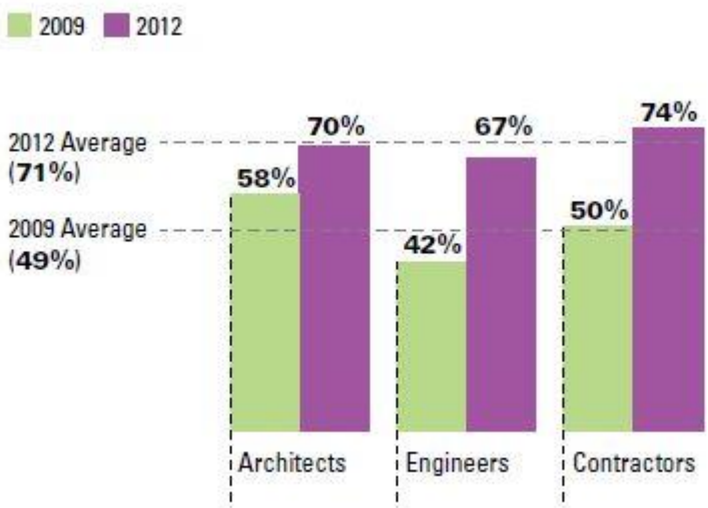

Figure 1.2 - BIM adoption by Stakeholders [2]

Nowadays, Construction and BIM technologies are built for the trailer and the office. To improve productivity e efficiency in construction, these technologies need to be built it for the field, where the work is done and money is spent. According to the Construction Industry Institute (CII) 75% of all construction dollars are spent in the field, however, 90 % of the technology is made for the trailer and the office. This, is one of the reasons for the low level of productivity associated to the AEC industry, where 25% of all construction dollars spent in the field are wasted, consequently there is the need to take BIM to the field. With field software like BIM 360 Field contractors now can start to change this reality and improve the productivity of the AEC Industry.

1.2. OBJECTIVES

Primarily, through the literature review, is intended to give a better understanding about BIM, its concept, capabilities, uses, benefits, risks, and difficulties, focusing in the construction sector, correcting at the same time some misconceptions associated to BIM.

Likewise, is the objective of this work, to present the potential gains and advantages of taking BIM to the field, through an empirical study of Autodesk's BIM platform, *BIM 360 Field* and their latent benefits.

Intending a better understanding and comprehension of what engaging BIM implies and represents, by construction management companies, is objective of this Master Thesis to provide a better knowledge, recommendations and guidelines into the path of adoption and implementing BIM.

1.3. OVERVIEW

The present dissertation is organized in six chapters. Firstly in the current chapter is given an brief introduction to the theme of this work, explaining its motivations, and goals.

In chapter 2 is given a brief historical background of the technology, presenting at the same time the thematic of BIM, describing some generalities about it, like definitions, software and tools, implementation, risks and benefits.

Chapter 3 focuses on the thematic of BIM for contractors and construction companies, associated to the problematic of the inefficiency involving this industry. In this chapter is also presented BIM 360 Field a FDMT from Autodesk aiming to overcome the existing gap in the construction site technology.

Chapter 4 consists in the analyse of a series of BIM 360 Field case-studies and the respective benefits perceived form it.

Regarding chapter 5 addresses the challenging thematic of BIM implementation directed for construction companies, providing recommendations and guide lines for a successful adoption.

The final chapter presents the main conclusions of this work and provides recommendations for future developments.

2
BIM - "BUILDING INFORMATION MODELLING"

2.1. BIM EVOLUTION

The conceptual fundaments of Building Information Modelling (BIM) go back to 1962, when Douglas C. Englebart in his paper "*Augmenting Human Intellect"* gives an extraordinary vision of the future Architect.

"The architect next begins to enter a series of specifications and data – a six-inch slab floor, twelve-inch concrete walls eight feet high within the excavation, and so on. When he has finished, the revised scene appears on the screen. A structure is taking shape. He examines it, adjusts it… These lists grow into an ever more-detailed, interlinked structure, which represents the maturing thought behind the actual design."

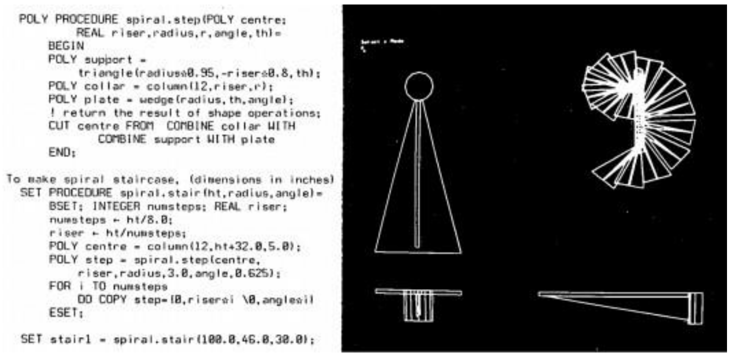

Figure 2.1 - GLIDE (programming input on the right and graphical interface on the left) [3]

It is perceptible that Englebart, in his paper, has already notions such as object based design, parametric modulation and relational database, which were at that time theoretical issues that with the evolution of computing sciences, modelling software's and visualisation interfaces become known as BIM. Through the System for Algebra and Geometry Experimentation (SAGE) graphical interface and the 1963, Ivan Sutherland's Sketchpad program, solid modelling programs start to present developments in the computational representation of geometry, which made possible to overcome the lack of a way to visualize the conceptual frameworks of object oriented programming. Charles Eastman expert in BIM, co-author of the "*BIM Handbook*" and professor at Georgia Tech school of Architecture developed the first successful project to address the issue of the relational database for construction components, with the creation of a building database, the Building Description System (BDS) which was the first software to describe individual library elements that can be retrieved and added to a model. In 1977 Eastman creates, at CMU, his next project; the Graphical Language for

Interactive Design (GLIDE –Figure 2.1) which presented, already at that time, most of the characteristics of a modern BIM Design Tool [4].

Eastman claims that drawings for construction are inefficient and cause redundancies of one object that is represented at several scales. He also criticizes hardcopy drawings for their tendency to decay over time and fail to represent the building as renovations occur and drawings are not updated. In a moment of prophecy, the notion of automated model review emerges to "check for design regularity" in a paper from 1974.

Using similar technology as the BDS in the Soviet Block two programming genius who would end up defining the BIM market as it is known today, Leonid Raiz and Gábor Bojár. They would go on to be the respective co-founder and founder of Revit (appendix A – page VII) and ArchiCAD (appendix A – page XXV). ArchiCAD was developed in 1982 in Budapest, Hungary by Gábor Bojár [4]. Due to Bojár struggle with an unfriendly business climate and software limitation ArchiCAD was not used on large scale projects until late 2000's.

Nearly at the same time, in the late 80's, two new trends that took BIM potentialities to what we know today started to arise. The development of specialized tools for multiple disciplines to serve and improve efficiency in the construction industry, like RUCAPS, the first program to use the concept of temporal phasing of construction processes. As well as the treatment of the building information model (bim) as an analysis prototype that could be tested and simulated against performance criteria like the Building Design Advisor, developed at Lawrence Berkley national Lab, in 1993.

Irwin Jungreis and Leonid Raiz founded in 1997, their own software company, Charles River Software with the objective of creating an Architectural software that could handle more complex projects than ArchiCAD, objective materialized in 2000 with the launching of Revit.

Revit revolutionized the world of Building Information Modelling by creating a platform that utilizes a visual programming environment for creating parametric families and allowing for time attributes to be added to a component, allowing a 'fourth-dimension' of time to be associated with the building model. This enables contractors to generate construction schedules based on the BIM models and simulate the construction process. One of the earliest projects to use Revit for design and construction scheduling was the Freedom Tower project in Manhattan. This project was completed in a series of separated but linked BIM models which were tied to schedules to provide real-time cost estimation and material quantities. Though the construction schedule of the Freedom Tower has been racked with political issues, improvements in coordination and efficiency on the construction site catalysed the development of integrated software that could be used to view and interact with architects, engineers and contractors models in overlay simultaneously. [4]

Nowadays there are a vast set of BIM software that could be used by the AEC industries stakeholders that will be addressed later on these work, focusing in the construction industry.

2.2. CONCEPT

As one of the most promising developments in the AEC industries and yet with no single, widely-accepted definition, the acronym BIM is used to describe the building information model, referred in this work as "bim" - which is, a project simulation consisting of the 3D models of the project components with links to all the required information connected with the project's planning, construction or operation and decommissioning [5] – and the Building Information Modelling "BIM" methodologies and processes – the management of information and the complex relationships between the social and technical resources that represent the complexity, collaboration, and interrelationships of today's organizations and environment, the focus is on managing projects to get the right information to the right place at the right time[6]. Due to the embedded complexity and different possibilities of use there are a lot of misconceptions about BIM, and so it is critical to firstly understand what BIM is not, in order to erase misconceptions and to be able to understand its concept..

2.2.1. WHAT IS NOT BIM

Disrupting the misconception created by software developers and vendors, who use the term BIM technology to describe their products, it is plausible to define as not being BIM technology tools that create the following kind of models:

- Models that contain 3D data only and no object attributes;
- Models with no support of behaviour;
- Models that are composed by multiple 2D CAD reference files that must be combined to define the building;
- Models that allow changes to dimensions in one view that are not automatically reflected in other views

.

Figure 2.2 . – 3D bim and some information retrieved from the model [7]

BIM is managing information to improve understanding. BIM is not CAD. BIM is not 3D. BIM is not application oriented. BIM maximizes the creation of value, up, down and across the build environment value network.[6] In a further manner:

- BIM is not a single building model or database, it actually is a series of interconnected models and databases creating relationships with each other and allowing information to be extracted and shared.
- BIM is not a replacement for people, it still is a lot of hard work, by reducing the mundane, BIM lets you work smarter [6], it is synonymous of different training, mind-set, and education.
- BIM is not perfect, in its essence it is information put in by people. Because people are not perfect there is always the possibility of incorrect data input, but since the data is only inserted once, reducing the repetitive input, there are less margin for errors, errors that creep in are easier to find, before they cause harm [6].

- BIM is not Revit, ArchiCAD or Tekla (appendix A – page VIX), these are BIM design Tools. It is the same as saying that “CAD” is “AutoCAD”. It is not uncommon to hear from people in the industry that their project is being done using BIM when what they really mean, is that the project is being done using Revit, although they are an important piece of BIM solutions they are not “the” BIM.
- BIM is not, neither has to be 3D. Although 3D models are great for visualization and have greatly improved the ability to communicate ideas, with 3D models people still have to interpret what things mean, how they relate and connect with each other and where they reside in space. BIM knows it all, knows how it relates to others, it is defined by standards, and can be shared. BIM is not a piece of software. It is not a 3D model. It is not a project phase. However it can be any or all of these [6].

2.2.2. What is BIM

So what is BIM? As previously said there is no single widely-accepted definition of BIM, as can be seen in the definitions given by five different parts involved with BIM.

The American National Institute of Building Sciences defines it as “*A computable representation of the physical and functional characteristics of a facility and its related project/life-cycle information using open industry standards to inform business decision making for realizing better value*”, the American Institute of Architects says it is “*Information use, reuse, and exchange with integrated 3D-2D model-based technology, of which electronic documents are just a single component (AEC Infosystems)*”. While the software developers like ArchiCAD, Bentley and Autodesk describe it as “*A single repository including both graphical documents - drawings - and non-graphical documents - specification, schedules, and other data*” (ArchiCAD); “*A modelling of both graphical and non-graphical aspect of the entire Building Life cycle in a federated database management system*”(Bentley); or even “*A building design and documentation methodology characterized by the creation and use of coordinated, internally consistent computable information about a building project in design and construction”* (AutoDesk).

In other words BIM is a set of software, 3D models, processes, and data bases. Meaning BIM starts with a 3D building model that is more than a simple visualization of geometry and textures added to the model, a true BIM model is the virtual equivalents of the actual building sections used to create a building, consisting these virtual elements in a prototype of the physical building elements that enables the simulation and understanding of the building behaviour previously to the actual construction begins. With these model is created a data base that is more than just architectural and engineering data, it creates data that is not visually represented in 3D, it contains scheduling information, which clarifies man power, coordination and anything that can impact the schedule, cost information that allows the perception of what the budget or estimated cost of a project might be at any given time of the project, as the impact in of modification in cost of the overall project. This information is not only useful during the design and construction phase of a building project, it can be used throughout the entire building life-cycle representing a reduction of the operation and management cost of the building which is significantly more than the entire cost of construction.

The nature of the components that make up a BIM (3D models and project information) will evolve throughout the development phase of a project. Duly resulting in a major change in the nature of both the 3D models and the linked information. This observation particularly serves to reinforce the importance of the process, rather than the model itself; building information modelling is a dynamic process. [5]

2.3. BIM SOFTWARE

Seeing the vast applicability of BIM is easy to comprehend the existence of a vast number of software associated to it.

Firstly is necessary to comprehend, that unlike the common belief and although the BIM community focus is in the "M", the model of BIM, making the most known software the modelling ones. BIM software is not only that, it is all software able to create, add, modify, view, delete, and use information, in other words manage the "I", in BIM.

There is also the need to comprehend some terms related to the BIM software:

BIM tool is all software application that manipulates the model in order to obtain a specific outcome. Examples of tools include those used for drawing production, rendering, visualization, specification writing, clash and error detection, energy analysis, cost estimation, scheduling and quantity take-off.

BIM application is a large class of any software that can be used to support Building Information Modelling Thus traditional applications such as drafting, rendering, specification writing and engineering analysis tools are all potentially BIM applications, if workflows and/or data exchange integrates them in Building Information Modelling.[8]

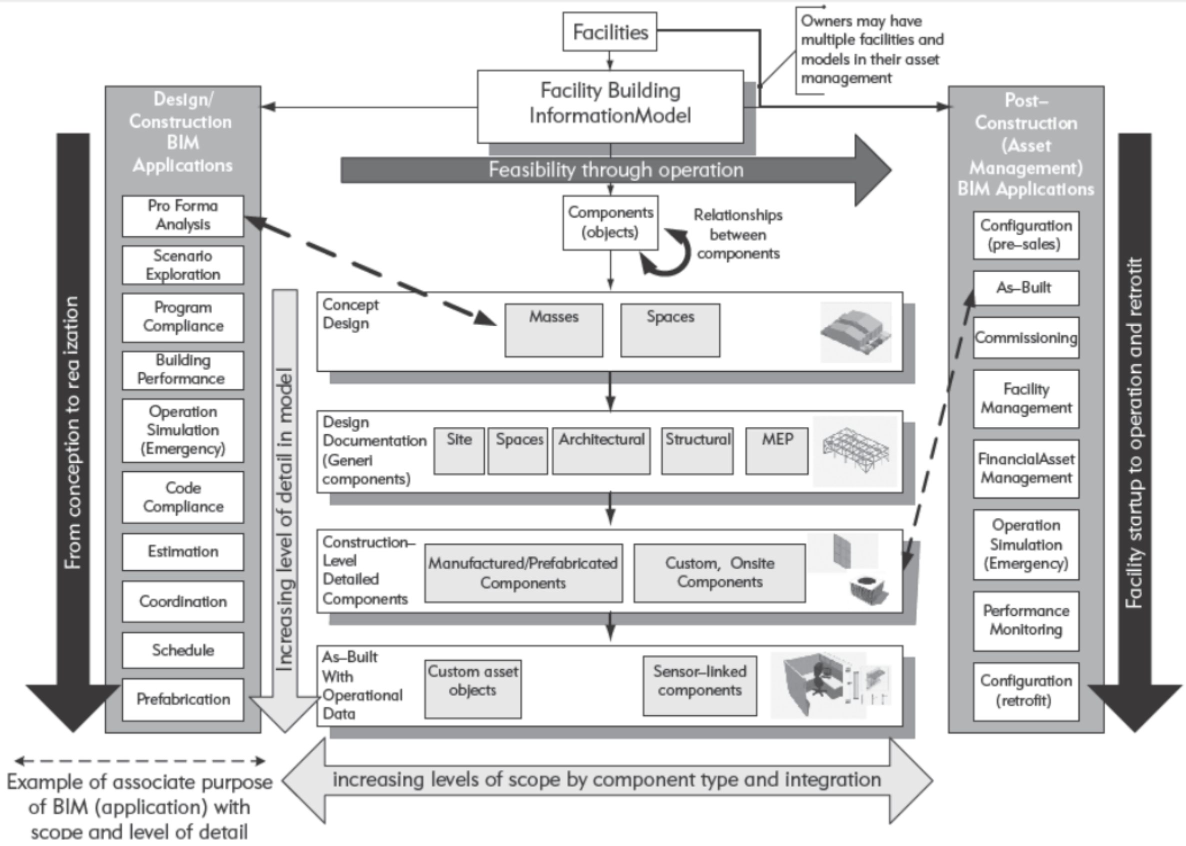

Figure 2.3 -– Conceptual diagram showing the relationship between various BIM applications [8]

BIM server is a database system whose schema is based on an object based format. It is different from existing project data management (PDM) systems and web-based project management systems. Those systems are file based systems, carrying CAD and analysis package project files. BIM servers are object-based, allowing query, transfer, update and management of individual project objects from a potentially heterogeneous set of applications. BIM servers are targeted to support BIM environments. .[8]

BIM platform is an application that generates data for multiple uses and incorporates multiple tools directly or through interfaces with varying levels of integration. This will be explored in further detail in this work through the analysis of the BIM platform of Autodesk, BIM 360 package, focusing the "Field" component, BIM 360 Field.

Through the different phases of the life-cycle of a building there are different needs, requirements, and stakeholders, therefore, it is obvious the existence of different benefits (Table 2.1), software applications (Figure 2.3) and tools to respond to this needs.

Table 2.1 - Some BIM application areas and potential benefits[8]

BIM application area	**Market Driver**	**Potential Benefits**
Space Planning and Program Compliance	Cost Management Marketplace Complexity	Ensure project requirements are met
Energy Analysis	Sustainability	Improve sustainability and energy efficiencies
Design Configuration/ Scenario Planning	Cost Management Complexity	Design quality communication
Building System Analysis/ Simulation	Sustainability	Building performance and quality
Design Communication/ Review	Marketplace Complexity and Language Barriers	Communication
Quantity Take-off and Cost Estimation	Cost Management	More reliable and accurate estimates
Design Coordination (clash detection)	Cost Management and Infrastructures Complexity	Reduce field errors and reduce construction costs
Schedule simulation/ 4D	Time to Market, Labor Shortages, and Language Barriers	Communicate schedule visually
Project Controls	Time to Market	Track project activities
Pre-Fabrication	Time to Market	Reduce onsite labor and improve design quality
Pro Forma Analysis	Cost Management	Improve cost reliability
Operations Simulation	Sustainability/ Cost Management	Building performance and maintainability
Asset Management	Asset Management	Facility and asset management

2.3.1. Owner Tools

Unlike the traditional approach, with BIM, owners no longer have to be resigned to the same level of typical construction projects problems, such as cost overruns, schedule delays and quality issues. With some tools, is possible for the owner to be more informed about the project, to better comprehend what designers are doing and therefore levelling his expectations. Reducing this way the later requests of change that ultimately impact design quality, construction cost, and time.

One tool used by owners to overcome the typical construction projects problems are estimating tools. These tools where already use before BIM, but with it the advantages thereof are much greater.

Owners use estimates to base line their project cost and perform financial forecasting or pro forma analyses. [8] Some estimating software design specifically for owners are, U.S. Cost Success Estimator, and Exactal's CostX. Through these, the owner can have a more reliable estimate early in the process. When associated with BIM quantity take-off tools, they deliver a faster, a better detailed and more accurate estimate. Thereby, making the struggle with the ability to respond and understand the design requirement changes and their impact on the overall project budget and estimate, a much easier and efficient process.

Further BIM tools used by owners are the "model checkers" that perform a variety of important functions such as checking against program requirements. This feature compares the design model with the owner requirements, spatial, energy, distance, and height requirements for example. Plus, validate the building information model checking the existence of duplicate components, components within components or components missing critical attributes, also checking the model for the existence of specific information types.

Besides the "model checkers" there are also the model review applications. These tools allow users to navigate through the model and query it interactively as well as to see sections or to view parts of the model. When considering this type of software the owners have to consider what type of features the project team will use (Table 2.2).

Since owners always seek for methods and technologies that enable them to deliver facilities faster, better, and cheaper, tools that optimize the scheduling management are as important as the previous ones. With tools and applications to automate design, simulate operations, and employ offsite fabrication, owners can better respond to some time to market needs:

- Through the use of parametric models that make design change easier and updates of documentation automatic, owners can see the time to market reduce. It also gives them the change to better respond to market trends or business missions closer to construction and adjust project requirements in collaboration with the design team;
- With the use of 3D coordination and prefabrication, the owner can see the schedule duration reduce due to the improvement of field productivity, reduction of field effort;
- With BIM-based planning there are reductions in the scheduling risk.

Lastly there are applications and tools that help owners to consider the energy efficiency of their facilities and the overall environment impact of their projects, specifically BIM analysis tools, that through the energy analysis can reduce the energy consumption of the facilities, evaluate the payoff and return on energy saving investments through life-cycle analysis, and BIM model creation and simulation tools that can improve operational productivity. Owing to 92%of operating costs are spent on the people who work in the facility [9] and taking into account studies that suggest that day-lighting in retail and offices improves productivity and reduces absenteeism [10], this tools and applications can help the owner to make his decisions between project cost and overall project requirements of different alternatives.

Table 2.2 - Model Review features to consider (Adapted from BIM Handbook)

File import features	What to consider?
Integrate models	Can the tool merge and integrate different types of file formats into one view and model?
Data import types	What types of non-geometric data does the tool import, and how can the user view the meta-data or model properties?
Multi-user support	Does the tool support multi-user access to a file or model or "shared" viewing of a model over the network?
Mark-up and comment tools	Can users mark up and comment in the tools? Are these mark-ups time stamped and tracked for review?
Model view support	Can the user view multiple views simultaneously? For example: plan, section, and 3d views?
Document view	Does the tool support viewing of related documents, such as text files or images or spread sheets?
Dimension queries	Can the user easily measure in 2D and 3D?
Property queries	Can user select a building object and view the object properties or perform a query to find all objects with a specific property or property value?
Clash-detection	Does the model review tool support clash-detection? If so, can you track the status of the clashes or classify the clashes?
4D	Does the model review tool include features to link the model objects to schedule activities or support other types of time-based simulations?
Re-organization of the model	Can the user re-organize the model into functional or user-defined groups and control viewing or other functions with these custom-defined groups?

2.3.2. Design Team Tools

Some of the potential design phase BIM software can be presented through two viewpoints, which apply in varying degrees to different projects, depending on their level of information development.

The first viewpoint concerning concept design and preliminary environmental analyses, appointing tools and applications to help and strengthening the process and decision making when generating the basic building plan, its sketch, defining the building's placement and orientation, and its structure.

Meant for the generation of the basic building plans and its sketch, 3D sketching tools, with due to the lack of information in the objects, are not BIM tools, but are useful tools in the BIM process, and can support quick generation of schematic design and rendering in a manner conveying the character of the proposed space and building shell.

For a more informed design with spatial needs defined, building placement, orientation and structure, exist space planning and 3D modelling tools. The spacing planning applications explicitly represent the spaces within a building but still lacks to support generation of layouts within the confines of a building shell, so despite provide another set of important schematic design capabilities it still is incomplete. In the other hand the 3D modelling tools can provide a schematic design without problems of interoperability and with the level of information needed at these phase.

Targeting the energy and environmental aspects of a candidate design, the environmental analysis tools present them themselves as crucial ones, providing performance feedback to the building model almost in real-time on design actions. These incorporate interfaces to a set of energy, artificial and natural lighting analyses, fire egress and other assessment applications, allowing quick analysis of schematic-level design.

The second viewpoint concerning the use of BIM software for design analysis/ simulation of building systems (Table 2.3), being these analyses addressing the operations measure the fluctuations of physical parameters that can be expected in the real building. The design of a building is where both viewpoints intercept through the 3D modelling tools.

Table 2.3 – Some analysis/ Simulation Applications [8]

		Import Formats					Export Formats					
	Application	**CIS/ 2**	**IFC**	**DXF**	**SDNF**	**SAT**	**GBXML**	**CIS/ 2**	**IFC**	**DXF**	**SDNF**	**Direct Link**
Structural Analysis	SAP200, ETABS	•	•					•	•			Revit ® Structures
	STAAD-Pro	•						•				Tekla Structures, Bentley
	RISA			•						•	•	Revit ® Structures
	GT-STRUDL	•			•			•				
	RAM							•		•	•	Revit ® Structures
	Robobat	•	•									Revit ® Structures
Energy Analysis	DOE-2											
	EnergyPlus		•				•		•	•		Ecotect
	Apache			•								IES
	ESP-r			•						•		Ecotect
Mechanical Equipment Simulation	TRNSYS											
	Carrier E20-II											
Lighting Analysis / Simulation	Radiance			•			•					ArchiCAD®
Acoustic Analysis	Ease			•								
	Odeon			•								
Air Flow / CFD	Flovent			•	•							
	Fluent											
	MicroFlo											IES
Building Funtion Analysis	EDM Model Checker		•									
	Solibri		•									

As the project evolves and the design proceeds, detail concerning the various systems must be determined in order to validate earlier estimates and to specify the systems for bidding, fabrication, and installation[8]. For that, there are analysis applications such as structural analysis applications capable of representing structural loads, load combinations, and the abstract behaviour of connections; energy analysis applications capable of representing the external shell for solar radiation, the internal zones and heat generation usages, and the HVAC mechanical plant; lighting simulation; acoustic analysis and air flow simulations applications are also useful tools however, with their own particular data needs are less understood by users and normally need some level of expertise to perform them.

Cost estimation tools show the same advantages as a tool for the design team as if for the owner. Furthermore as a tool for the design team, it allows them to carry out value engineering while they are designing; considering alternatives as they design that make best use of the client's resources.

Applications and tools referring to the development of the construction model, their uses and advantages will be addressed further on in this work, in chapter 3, as well as the applications and tools for the construction team.

2.3.3. Facility Manager Tools

From most facility manager's perspective, managing spaces and their related equipment and facility assets does not require 3D information; but 3D component-based models can add value to facility management functions. Building models provide significant benefits in the initial phase of entering facility information and interacting with it. For this and other facility manager function there are the Facility management (FM) Systems that, must have besides the general features not related to BIM, a merging capability, support space objects, and permit the update of the model in case of retrofit or reconfiguration of the facility.

In addition the operation simulation tools can help the facility manager to have a better idea of how the facility behaves in case of emergency and help him to improve those scenarios. These tools are listed in the Table 2.4.

Table 2.4 -Operation Simulation Tools (adapted from [8])

Simulation type	Company and Software Name	Input BIM?
Crowd behaviour	Legion Studio	No
	eRENA ViCROWD	No
	Crowd Dynamics	No
Evacuation	IES Simulex	Yes (via gbXML or DXF file)
	buildingExodus	No (DXF File)
Operation	Common Point OpSim	Yes (geometry)
	buildingExodus	No (DXF File)
Systems	SIMSuite	
	Flex-Sim	

2.4. Interoperability

The design and construction of a building is a team activity and increasingly each activity and each type of specialty is supported and augmented by its own computer application. Nevertheless no single computer application can support all of the tasks associated with building design and production.

Interoperability depicts the need to pass data between applications, eliminating the need to replicate data input, allowing multiple types of experts and applications to contribute to the work, and facilitating smooth workflows and automation.

In 2009 McGraw-Hill surveys on BIM, identify interoperability as the largest issue for advanced BIM users. [11]. Being such an important issue, there are some ways to address it, mainly through different kind of exchange formats (Table 2.5).

Data exchange between applications can be carried out in different ways:

- Direct, proprietary links between specific BIM tools;
- Proprietary file exchange formats, primarily dealing with geometry;
- Public product data model exchange formats;
- XML (eXtensible Markup Language) -based exchange formats.

Some well-known proprietary exchange format in the AEC area is the DXF (Data eXchange Format) defined by Autodesk, as well as SAT (defined by Spatial Technology, the implementer of the ACIS geometric modelling software kernel), STL for stereo-lithography and 3DS for 3D-Studio.In result each one of these has their own purpose, and addresses functionally specific capabilities.

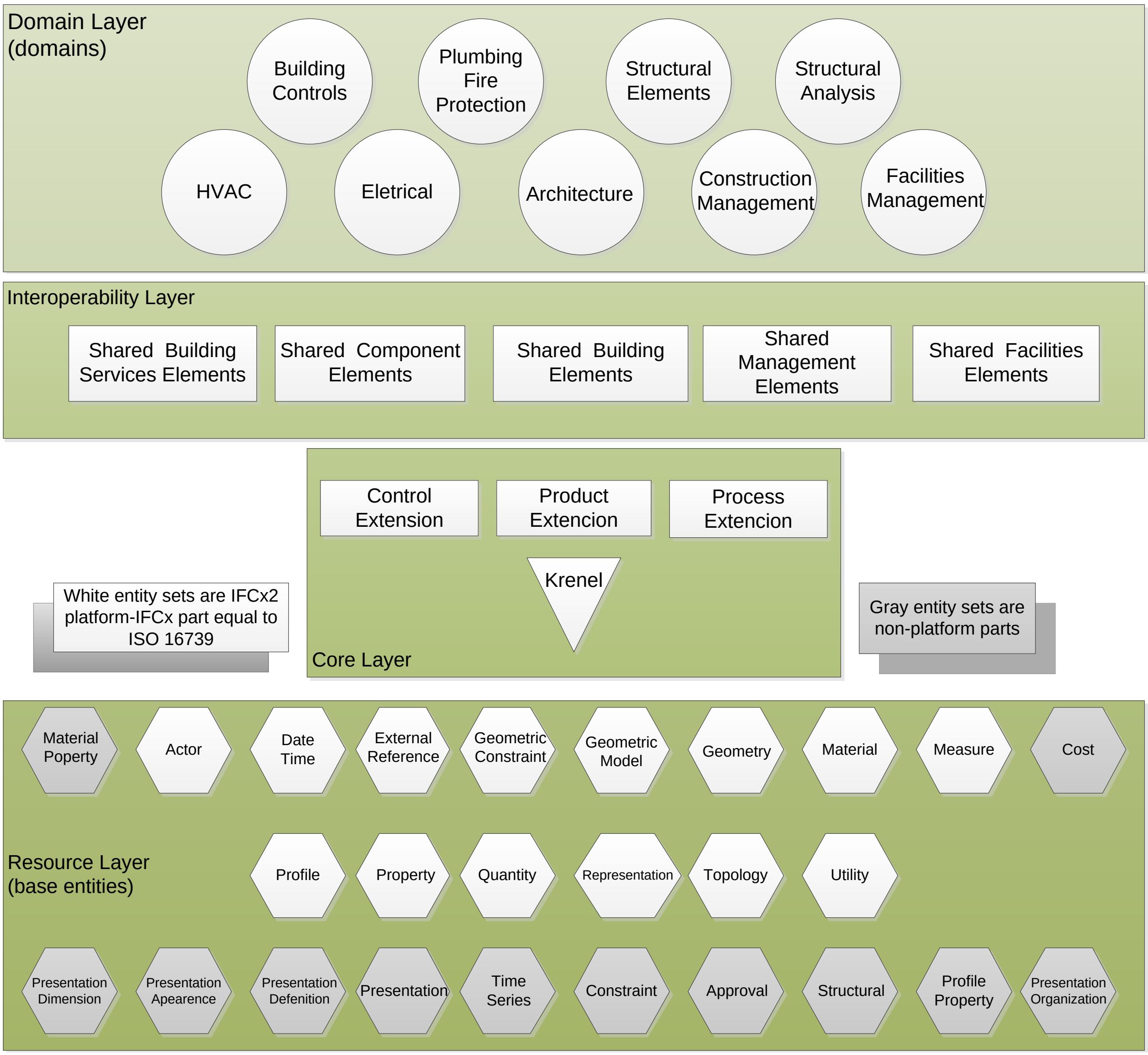

Figure 2.4 - The system architecture of IFC subschemas (Adapted from [8])

Besides proprietary exchanges, open standards such as IFC (Industry Foundation Class) and CIS/ 2 for steel, facilitate interoperability. The IFC is an object-based file format with a data model developed by buildingSMART of the International Alliance for Interoperability (IAI). It is an open standard as previous said that is registered by ISO so is an official International Standard (ISO 16739:2013) and relies on the ISO-STEP EXPRESS language and concept for its definition, with a few minor restrictions on the language .

The ISO 16739:2013 like its previous versions consists of data schema, represented as an EXPRESS schema specification, and reference data, represented as definitions of property and quantity names and descriptions [12].The conceptual organization of IFC *entities* (objects in EXPRESS) are diagrammed in Figure 2.4. The data schema and referenced data are referred to as a model view definition, defined to support one or many recognized workflows in the AEC industry, for which is identified the data exchange requirements for software applications. Within its scope are:

- Exchange format definitions required through the life cycle of a building: demonstrating the need; conception of need; outline feasibility; substantive feasibility study and outline financial authority; outline conceptual design; full conceptual design; coordinated design; procurement and full financial authority; production information; construction; and operation and maintenance.[12]
- Exchange format definitions required by the various disciplines involved: architecture; building service; structural engineering; procurement; construction planning; facility management; project management; client requirement management; building authority for permits and approval. [12]
- Exchange format definitions including: project structure; physical components; spatial components; analysis items; processes; resources; controls; actors; context definition. [12]

However it leaves out behavioural aspects of components and other information items, exchange format definitions outside of the domain of the AEC industry, project structure and component breakdown structures outside of building engineering.

Another alternative way to exchange data is through XML, an extension to HTML. XML allows definition of the structure and meaning of some data of interest. The different XML schemas support exchange of many types of data between applications. XML is especially good exchanging small amounts of business data between two applications set up for such exchanges.

Aside from these efforts to standardization of the data structures dealing with geometry, relations, and attributes, there are other BIM-related standards efforts, such as: the international framework for dictionaries that develops mapping of terms between different languages; the OmniClass which deals with review and replacement of existing building-related classification systems; the COBie (Construction Operations Building information exchange), addresses the handover of information between the construction team and the owner. It deals with operations and maintenance (O&M), as well as more general facility management information.

Image (raster) Formats	
JPG, GIF, TIF, BMP, PIC, PNG, RAW, TGA, RLE	Raster formats vary in terms of compactness, number of possible colours per pixel, some compress with some data loss.
2D Vector formats	
DXF, DWG, AI, CGM, EMF, IGS, WMF, DGN	Vector formats vary regarding compactness, line widths and pattern control, colour, layering and types of curves supported
3D Surface and Shape formats	
3DS, WRL, STL, IGS, SAT, DXF, DWG, OBJ, DGN, PDF(3D), XGL, DWF, U3D, IPT,PTS	3D surface and shape formats vary according to the types of surfaces and edges represented, whether they represent surfaces and/ or solids, any material properties of the shape or viewpoint information.
3D Object Exchange formats	
STP, EXP, CIS/2	Product data model formats represent geometry according to the 2D or 3D types represented. They also carry object properties and relations between objects.
Game formats	
RWQ, X, GOF, FACT	Game files formats vary according to the types of surfaces, whether they carry hierarchical structure, types of material properties, texture and bump map parameters, animation and skinning.
GIS formats	
SHP, SHX, DBF, DEM, NED	Geographical information system formats
XML formats	
AecXML, Obix, AEX, bcXML, AGCxml	XML schemas developed for the exchange of building data. They vary according to the information exchange and the workflows supported.

Table 2.5 - Common exchange formats in AEC applications [8]

2.5. The BIM Process

The process of BIM is revolutionary because it provides the opportunity to migrate from practices that are centred on human craftsmanship to a more augmented and modern machine craftsmanship - and all that this might imply. It provides the basis for construction companies to save time and money by rapidly creating simulations (time/cost/constructability) allowing to plan and virtually test a design anticipating problems before they become highly expensive. In more detail, the BIM process facilitates all aspects of the project, and can be divided into four main processes:

- The processes enabling the owner to develop an accurate understanding of the project;
- The processes enabling the design, development, and analysis of the project;
- The processes enabling the management of the construction of the project (which will be deeply addressed further in this work);
- The processes related to the management of the operations of the project during its actual use. [11]

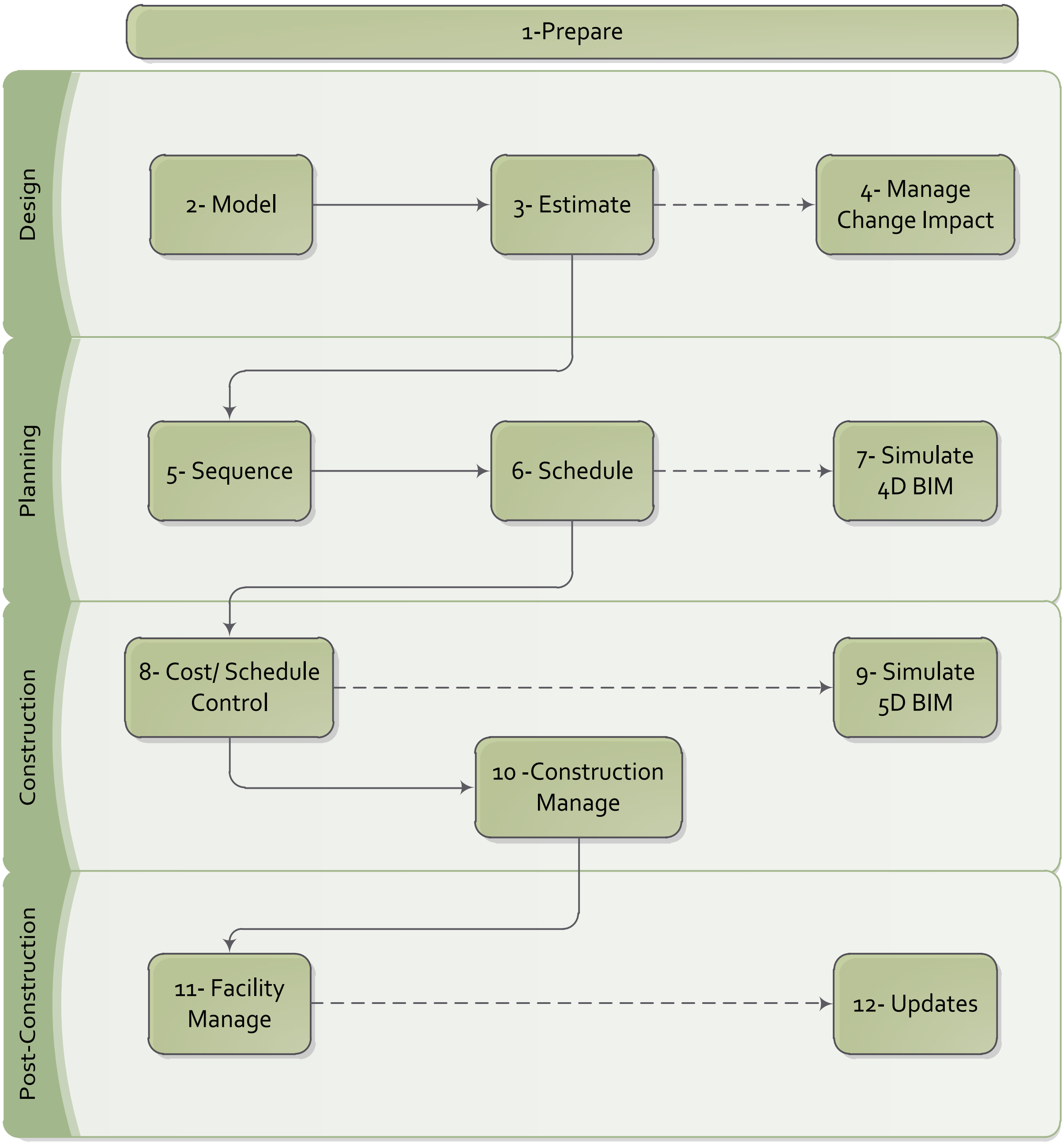

Figure 2.5 . – BIM Process work flow (Adapted from [13])

The AEC industry is not accustomed to think about and analyse the business processes in a methodical way, there is a fearsome number of business processes and workflows that are undocumented [14] and fragmented which do not allow information to flow freely. This happen because to manage information using the traditional paper-based information methods, the AEC industry has been obligated to compartmentalize the information. With BIM there is no longer the need to be restricted to those methods.

It is crucial to understand that processes are intrinsically connected to each organization's structure, workflow and market; consequently there is no "correct" approach to it. However, there are some good practices and aspects of business process reform and changes that should be considered as part of any BIM implementation and process:

- Reduction of manual data entry with a greater electronic information exchange;
- Reduction and elimination of low-value and no-value tasks;
- Reduction of time spent on "defensive documentation";
- Integration of construction cost estimating with building information modelling;
- Reorganization of business processes to enable more tasks to occur concurrently;
- Increased prefabrication of construction assemblies;
- Implementation of direct design-to-fabrication processes
- Implementation of efforts to achieve and maintain optimal performance of operating systems and equipment;
- Implementation of continuous learning processes to improve the quality and profitability of the operations.

Once again BIM and related technology may be of incredible use in this change, but the fundamental issue is how information is used in order to improve the way business is done.

Through time there has been a large amount of approaches to business process, which result in failure. In order to implement the BIM process, is needed another major change. Lest end up as another failure and produce results, business leaders cannot approach it with an extreme top-down leadership, instead they need to find equilibrium between the rigid leadership and an employee's support leadership, understanding at the same time how to transform their organizations.

2.6. BIM IMPLEMENTATION

Implementing Building Information Modelling is much more of a business decision than a technical one. BIM is an enabling technology with the potential for improving communication among business partners, improving the quality of information available for decision making, improving the quality of service delivered, reducing cycle time, and reducing cost at every stage in the life cycle of a building. [14]

For many business owners and senior managers throughout the AEC industry, there are only three key criteria that define the organization entire BIM implementation strategy: which software application to buy; the number of software licenses to purchase and the number of staff members to send to training.

These are troubling business phenomena. When compared with other decisions other than technology; the same business leaders would consider the allocation of significant capital resources in the absence of a clearly defined business strategy highly irresponsible. Successful business leaders develop business strategies to distinguish their companies from their competition. They examine their business needs and select products and services that meet them. They don't base their decision on the popularity of a product among their competitors, nor put the selection of a single product or service at the centre of a comprehensive business strategy.

This undisciplined approach to technology deployment in the building industry must change, if for no other reason than that we have failed to achieve the productivity gains realized in other industries over the same period (Figure 2.6).

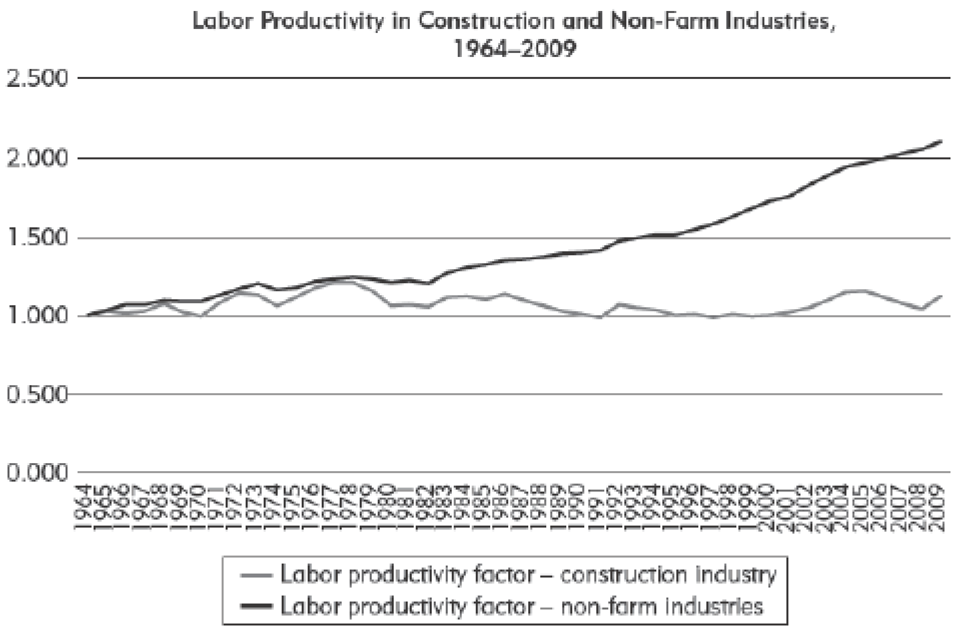

Figure 2.6 - Indexes of labour productivity for construction and non-farm industries, 1964-2009, [8]

Owners must start realizing that to achieve the full potential of the technology; they cannot realize it with a narrow focus. When compared with the potential impact on the organization's profitability resulting from the implementation of BIM, the cost of software and training are secondary. (Figure 2.7)

Furthermore is important to point out that software developers instead of developing tools to create and sustain a single building information model, are creating tools that allow each player in the building life cycle to intervene.

For a BIM implementation strategy to be fully effective, software training must be preceded by, or at least accompanied by, education. Training teaches people how to do. Education teaches people how to think. Employees trained to use a BIM application will learn how to perform tasks, not how to improve or change business process, which only business leaders can do. An effective (and documented) BIM implementation strategy is necessary to provide the framework for an effective BIM training program. [14]

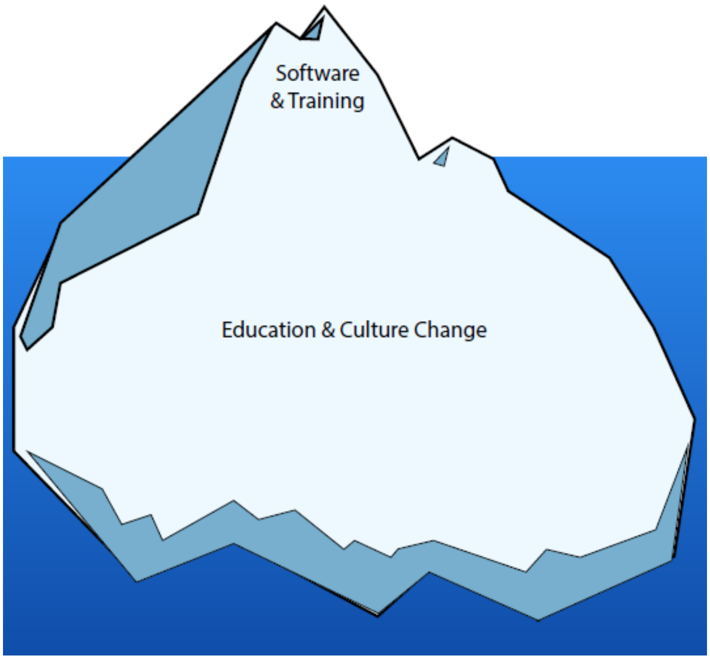

Figure 2.7- The Hidden Costs and Benefits of BIM [14]

2.6.1. Business Operations and BIM Implementation

A successful BIM implementation will inevitably affect the products and services of a company as well as its general business operations. Following and implementing some basic concepts of BIM, will help streamline business operations, establish a consistent working environment for the employees and business partners, and increase the percentage the organization's total work effort that is devoted to value-added tasks. Some of these concepts are easy to comprehend, and in a greater point of view are just good business practices, such as:

- Ensuring that data is entered only once during the building information life-cycle, by the most authoritative source;
- Sending and receiving data in the most structured electronic form possible;
- Integrating data entry and data maintenance tasks into the company's business process;
- Collecting all relevant information at the first time;
- Emphasizing the value of data collection and data quality;
- Adopting open standards whenever possible.

Besides the value and change brought by these concepts to the organization, there are certain major changes that need to take place in the entire business operations and workflows. The major affected functional areas by BIM implementation are the Marketing/Business development, Human Resources, Finance, Information Technology, and Operations.

Regardless of the organizational structure and culture of the marketing function in a company, is most likely that whoever is responsible for this area as no experience with BIM. Therefore is extremely important that the company's professional team and marketing team can collaborate and communicate intensively, in order to, the team of marketing develop knowledge about what kind of services and

BIM expertise the company can offer to prospective clients, levelling in this manner their expectations, neither overpromising nor under promising.

The refurbishment of the Human resources area derives from two reasons, the rising need for BIM-savvy people, with a higher level of technical skill and knowledge, and most likely the creation, management of a new department in the company. This new BIM department perform the tasks related directly to BIM such as clash detection, coordination, phase modelling, among others, in which the main players are:

- The BIM Lead, who manages the different teams that are working on-site or from home base on different projects, or to manage a sub-group that still falls under the BIM group's jurisdiction. [15]
- The BIM Manager, who oversees the entire BIM group. In some larger organizations there is also a Director of BIM services will oversee multiple BIM groups within the organizations' multiple offices. [15]
- BIM Detailers that are what make BIM projects run proficiently, and should be considered the oil to your BIM machine. The level of BIM knowledge and experience of the BIM detailers is not always the same, for instance a "BIM Detailer I" requires only minimal history with BIM Projects and only needs to know AutoCAD and 3D basics, while a BIM Detailer IV would require an extensive past in BIM and be a certified professional in the programs you are using.[15]

Moreover, is important to point out the necessity of employers, through the human resources department, to rapidly develop BIM and project delivery skills internally due to the fact that institutions of higher learning will be unable to satisfy the industry demand of highly qualified personnel in this area.

Regarding the finance area in business the major impact of BIM is in the financial management, which main goal is to manage the firm's resources effectively in order to achieve an establish profit target. In the AEC industry, this is a very tricky and extremely challenging task. This manifestation is understandable giving the high ambiguity and uncertainty associated with to the building design and construction process. BIM will not eliminate the risk associated to this task; instead it will reduce it by constructing the building virtually, before it is built, allowing the project teams to discover and correct mistakes much earlier in the process, far more quickly and with lower costs and effort associated as represented in Figure 2.8. Also helping to reduce this risk is the possibility of analyse the detail model for optimum construction sequencing and scheduling, which all together allows for a greatly improved financial forecasts.

Unlike the other functional areas, the Information Technology (IT), is an area that normally is given an strategic status like revenue-generating or value-added business operations. This is a typical error that should be avoided. The appropriate status for IT is a vital support function, just as human resources, marketing and finance it is a cost centre, not a profit centre and mainly it should not be equated or confused with BIM. Although IT should not be confused with BIM, that is an integral part of the revenue-generating value added business operation, it should have the necessary financial, personnel and technical resources it needs to provide the IT infrastructure that the company needs. In contrast to the time when software was bought as a workstation product on per-seat-licence basis, nowadays there far more flexible ways to purchase software such as: enterprise licensing; concurrent user license or Web-based software as a service -like BIM 360 Field – that can help minimizing the IT infrastructure needs.

All of this four support functions must be responsive to change in the revenue-generating and value-added operations, which represents the way a company do business and the most affected aspect in a company BIM implementation. The centre of the operations work-flow in the AEC industry is the information and the way information flows, when the flow of information stops the work stops.

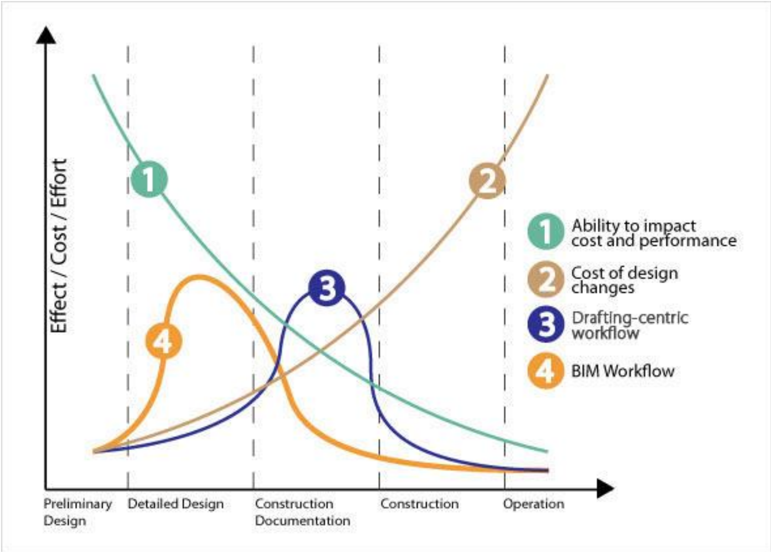

Figure 2.8 - Design Effort and Cost of Change [16]

For a successful BIM implementation it is needed a well streamlined work-flow and information flow than can be achieved using tools that allow the revising of methodical, documented way, like the Business Process Modelling Notation. This workflow modelling process should be supported by a clear strategic planning process containing an honest analysis of the organization's strengths and weaknesses, in order to determine the specific markets, the Regional business culture and it place in the industry as a whole.

2.6.2. Measuring Progress

Besides the fact that is difficult to establish goals and define objective metrics for measuring progress in BIM implementation involving business relationships, enterprise workflows, project delivery methods, staff skill and training, and the design process; it is still possible. A good first step for design companies toward that, is the Capability Maturity Model (CMM) of the National Building Information Modelling Standard (NBIMS), design to measure the "maturity" of a building information model and process used to create it through a benchmark (Table 2.6). It identifies eleven categories of maturity, each of which can be scored on a scale one to ten. Those eleven categories of maturity are:

Table 2.6 - Capability Maturity Mode, CMM (Source: NIBS)

Maturity Level	A Data Richness	B Life Cycle Views	C Roles or Disciplines	D Business Process (BP)	E Delivery Method	F Timeliness/ Response	G Change Management (CM)	H Graphical information	I Spatial Capability	J Information Accuracy	K Interoperability/ IFC Support
1	Basic Core Data	No Complete Project Phase	No Single Role Fully Supported	Separate Processes Not Integrated	Single Point Access no Information Assurance	Most Response Info manualy re-collected - Slow	No CM Capability	Primarily Text No Technical Graphics	Not Spatial Located	No Ground Truth	No Interoperability
2	Expanded Data Set	Planning & Design	Only one role Supported	Few BP Collect Info	Single Point Access w/Limited IA	Most Response info manualy re-collected	Aware of CM	2D Non-Intelligent as Designed	Basic Spatial Location	Initial Ground Truth	Forced Interoperability
3	Enchanced Data Set	Add Construction/ Supply	Two Roles Partially Supported	Some BP Collect Info	Network Access w/Basic IA	Data Calls not in bim bur Most other Data is	Aware of CM and RCA	NCS 2D Non-Intelligent as Designed	Spatially Located	Limited Ground Truth - Int Spaces	Limited Interoperability
4	Data Plus Some Information	Includes Construction/ Supplly	Two Roles Fully Supported	Most BP Collect Info	Network Access w/Full IA	Limited Response info Available in bim	Aware of CM, RCA and Feedback	NCS 2D Intelligent as Designed	Located W/ Limited Info Sharing	Full Ground Truth - Int Spaces	Limited Info Transfers between COTS
5	Data Plus Expanded Information	Includes Constr/ Supply & Fabrication	Partial Plan, Design, & Construction Supported	All BP Collect Info	Limited Web Enabled Services	Most Response info Available in bim	Implementing CM	NCS 2D Intelligent As-Builts	Spatially Located w/Metadata	Limited Ground Truth - Int & Ext	Most Info Transfers Between COTS
6	Data w/Limited Authoritative information	Add Limited Operations & Warranty	Plan, Design, & Construction Supported	Few BP Collect & Maintain Info	Full Web Enabled	All Response info Available in bim	Initial CM process Implemented	NCS 2D Intelligent And Current	Spatially Located w/Full Info Share	Full Ground Truth - Int & Ext	Full Info Transfers between COTS
7	Data w/Mostly Authoritative information	Includes Operations & Warranty	Partial Ops & Sustainment Supported	Some BP Collect & Maintain Info	Full Web Enabled w/IA	All Response info from bim & Timely	CM process in place and early implementation of RCA	3D Intelligent Graphics	Part of a limited GIS	Limited Comp Areas & Ground Truth	Limited Info uses IFC's
8	Completely Authoriative Information	Add Financial	Operations & Sustainment Supported	All BP Collect & Maintain Info	Web Enabled service - Secure	Limited Real-Time Access From bim	CM and RCA capability implemented and in use	3D Current and Intelligent	Part of a more complete GIS	Full Comp Areas & Ground Truth	Expanded Info uses IFC's
9	Limited Knowledge Management	Full Facility Life Cycle Collection	All Life-Cycle Roles Supported	Some BP Collect & Maintain Info in Real Time	Net Centric SOA based w/CAC Access	Full Real-Time Access From bim	BP sustained by CM using RCA and Feedback Loops	4D and Time	Integrated into a complete GIS	Comp GT w/Limited Metrics	Most info uses IFC's
10	Full Knowledge Management	Support External Efforts	Internal & External Roles Supported	All BP Collect & Maintain Info in Real Time	Net Centric SOA Role based CAC	Real-Time Access w/ live Feeds	BP routinely sustained by CM, RCA and Feedback Loops	nD Time & Cost	Integrated into GIS w/Full info Flow	Computed Ground Truth w/Full Metrics	All info uses IFC's

- Data Richness referent to the degree to which a building information model encompasses the available information about a building;

Table 2.7 -Data Richness CMM (Source: NIBS)

Maturity Level	Data Richness
1	BIM is established with only a very basic data set.
2	Expanded BIM's data set.
3	Enhanced BIM's data set, allowing to rely on the model for basic data.
4	Data is turned into Information.
5	Data begins to be accepted as authoritative and the primary source.
6	Some metadata is stored and information is typically best available.
7	Most users rely on information as reliable and authoritative; little Additional data checking is required.
8	The information has metadata and is authoritative source.
9	Limited Knowledge Management implies that KM strategies are in place and authoritative information is beginning to be linked.
10	Full Knowledge Management implies a robust data-rich environment, with virtually all authoritative information loaded and linked together.

- Life Cycle Views referent to the degree to which a building information model can be viewed (and used) appropriately by any players throughout the life cycle of the building;

Table 2.8 - Life Cycle Views CMM (Source: NIBS)

Maturity Level	Lifecycle Views
1	Data is gathered as it is available but no single phase is authoritative or complete.
2	Since basic initial data is collected during planning and design, this is typically the first phase to be made available, but can be any phase such as construction.
3	An additional phase is available, typically construction; however, the two phases do not necessarily need to be linked.
4	A third phase is added; although information does not have to be flowing, it is assumed that some is.
5	A fourth phase of the facility life cycle is added and some information is flowing.
6	Na additional phase is added and clearly information is flowing to operations from design and construction phases.
7	Information collected during earlier phases is flowing to operations and sustainment.
8	A cost model is supported and costs are linked to the information related to all phases. Life cycle costing can be performed.
9	All phases of the life cycle are supported and information is flowing between phases.
10	External information is linked into the model and analysis can be performed on the entire ecosystem of the facility throughout its life.

- Roles or Disciplines referent to the number of building-related disciplines that are accommodated in the modelling environment, and how well information flows from one to another;

Table 2.9 -Roles or Disciplines CMM (Source: NIBS)

Maturity Level	Roles or Disciplines
1	Roles apply to people's jobs, and at this level no one's role is fully supported through the BIM
2	Roles apply to people's jobs, and at this level there is one person's role that is fully supported through the BIM
3	Roles apply to people's jobs, and at this level there are at least two people's roles that are partially supported through the BIM but they still have to go to other products to accomplish their jobs.
4	Roles apply to people's jobs, and at this level there are at least two people's roles that are fully supported through the BIM but they still have to go to other products to accomplish their jobs.
5	People's jobs in planning and design are fully supported through the BIM in that they do not have to go to other products to accomplish their jobs.
6	People's jobs in planning, design and construction are fully supported through the BIM in that they do not have to go to other products to accomplish their jobs.
7	People's jobs in planning, design and construction are fully supported and operations and sustainment are partially supported through the BIM in that they do not have to go to other products to accomplish their jobs.
8	People's jobs in planning, design and construction are fully supported and operations and sustainment are fully supported through the BIM in that they do not have to go to other products to accomplish their jobs.
9	All facility-related jobs throughout the life-cycle of the facility rely solely on the BIM to accomplish their jobs
10	All facility-related jobs both internal and external to the organization rely solely on the BIM to accomplish their jobs

- Business Process referent to the degree to which business processes are designed and implemented to capture information routinely in the bim;

Table 2.10 -Business Process CMM (Source: NIBS)

Maturity Level	Business Process (BP)
1	BP are not defined and therefore not used to store information in the BIM
2	Few BP are designed to collect information to maintain the BIM in the organization.
3	Some BP are designed to collect information to maintain the BIM in the organization.
4	Most BP are designed to collect information to maintain the BIM in the organization.
5	All BP are designed to collect information as they are performed.
6	All BP are designed to collect information as they are performed but few are capable of maintaining information in the BIM.
7	All BP are designed to collect information as they are preformed and some are capable of maintaining information in the BIM.
8	All BP are designed to collect information as they are preformed and all are capable of maintaining information in the BIM.
9	All BP are designed to collect and some maintain data in real time.
10	All BP are designed to collect and maintain data in real time.

- Change Management referent to the degree to which an organization has developed a documented methodology for changing its business processes;

Table 2.11 - Change Management CMM (Source: NIBS)

Maturity Level	Change Management (CM)
1	No CM process awareness is evident, nor has it been implemented in the organization.
2	There is an early awareness of the need for business process definition and change management in the organization, although implementation is not yet initiated.
3	Early implementation of business process definition is underway, there is an early awareness of the need for BP definition, and there is an awareness of CM and the need for RCA in the organization.
4	BP are in place and there is an understanding of the full CM requirement to include RCA and implementation feedback loop.
5	BP are in place and the organization has begun implementing CM procedures.
6	BP are in place and early CM processes are identifying changes, but no process is in place to make changes.
7	Early implementation of CM is in place and some processes are being maintained through RCA process.
8	Implementation of a CM process is in place and is beginning to be exercised, but is not fully endorsed by all participants.
9	The CM processes are in place, but are not efficient, and chages typically take more than 48 hours.
10	A mature and fully operational CM process is in place and process changes are implemented within 48 hours.

- Delivery Method referent to the robustness of the IT environment to support data exchange and information assurance;

Table 2.12 - Delivery Method CMM (Source: NIBS)

Maturity Level	Delivery Method
1	The BIM is only accessible from a single workstation and has no information assurance built in.
2	The BIM is not on a network but there is control over who can access the BIM.
3	The BIM is on a network and there is basic password control over data entry and retrieval.
4	The BIM is on a network and there is control over data entry and retrieval.
5	The BIM is in a limited Web environment typically found in a single office environment; IA is not in place to control data entry or retrieval.
6	The BIM is Web enabled but IA is not in place, although there is some control to access of the information. This environment would be found in a single office/ company.
7	The BIM is in a Web environment so multiple people can operate on it and there is role-based IA manually controlled.
8	The BIM is in a Web-enabled environment and is considered secure. It is not an SOA.
9	The BIM is in a net centric Web environment and is served up as a service in a service-oriented architecture and CAC enabled but roles must be managed manually.
10	The BIM is in a net centric Web environment and is served up as a service in a service-oriented architecture with role-based CAC enabled to enter and access information.

- Timeliness/Response measures the degree to which BIM information is sufficiently complete, up-to-date, and accessible to users throughout the life cycle;

Table 2.13 - Timeliness/Response CMM (Source: NIBS)

Maturity Level	Timeliness/ Response
1	Information is re-collected when needed to respond to a question - the process is slow and un-automated and has to be reinvented each time a question is asked.
2	Most of the information needed to respond to a question must be collected to respond to the question; however, there is awareness of how to obtain the information.
3	Most information is in the BIM; however, many responses to data calls involve collection of data, which is then stored in the BIM.
4	Information is stored in the BIM and many data calls can be answered with information that is already in the BIM.
5	A significant portion of the response information related to a facility is stored in the BIM.
6	Responses to data calls related to the facility are primarily stored in the BIM.
7	All emergency response information is in the BIM and that is considered the primary source of accurate information.
8	Information stored in a BIM is available real time and although not from a live feed. Processes are in place to maintain its accuracy.
9	The information is stored in a BIM and is current enough to be a reliable source for information in an emergency.
10	Information is continually updated and available from live feeds to sensors. Responses to questions are almost immediate and are accurate and relational.

- Graphical Information referent to the degree of sophistication or embodied intelligence of graphical information;

Table 2.14 - Graphical Information CMM (Source: NIBS)

Maturity Level	Graphical Information
1	There are no graphics in the BIM, only text.
2	2D drawings are stored in the BIM but there is no interaction with information; the drawings were not developed with NCS.
3	The drawings stored were developed with NCS yet are still non intelligent and not object oriented.
4	The drawings are 2D but are intelligent - a wall recognizes itself as a wall with properties but they are as design and not as built.
5	The drawings are 2D and are intelligent - a wall recognizes itself as a wall with properties and they are as built but not current.
6	The drawings are 2D and are intelligent - a wall recognizes itself as a wall with properties and they are current.
7	The drawings are 3D object based and have intelligence.
8	The drawings are 3D object based and have a process in place to keep them current.
9	Time phasing has been added to the drawings so that one can see historical elements as well as being able to project into the future.
10	The drawings stored in the BIM are intelligent and object-based and include time and cost information.

- Spatial Capability referent to the degree to which the building information model is spatially located in the real world according to Geographic Information Systems (GIS) standards;

Table 2.15 - Spatial Capability CMM (Source: NIBS)

Maturity Level	Spatial Capability
1	The facility is not spatially located using GPS or GIS
2	A basic Location has been established using GPS so that one can locate the facility spatially.
3	The facility is recognized in a worldwide spatially but no information is shared between the bim and GIS.
4	The facility is spatially located and some information is shared with the GIS environment.
5	The facility is spatially located and information can be shared with the GIS environment although it is not integrated and interoperable.
6	The facility is located spatially and there is full information sharing between the BIM and GIS.
7	The BIM has been partially integrated into the GIS environment.
8	Information from the BIM is recognized on a limited basis by the GIS.
9	Information from the BIM is partially recognized by the GIS environment and some metadata is available.
10	Information from the BIM is fully recognized by the GIS environment, including full metadata interaction.

- Information Accuracy measures the degree to which information reflects real-world conditions;

Table 2.16 - Information Accuracy CMM (Source: NIBS)

Maturity Level	Information Accuracy
1	There is no ground truth and information is simply loaded into the system manually or unverified electronically.
2	There is some electronic validation of information for internal spaces.
3	Space is calculated electronically and not stored as a separate data element for internal spaces.
4	Internal Spaces are identified electronically and some outside information is electronically calculated.
5	Many spaces and items are identified electronically yet some items are still entered manually, both internally and externally.
6	All internal and external spaces are identified electronically and some outside information is electronically calculated.
7	Internal spaces are computed electronically and some outside information es electronically calculated.
8	All units are calculated electronically and reported. If a polygon changes shape, then the updated information flows throughout the model.
9	All internal and external areas computed and some metrics have been established to track compliance.
10	All Spaces are calculated automatically and metrics are used to ensure information is available and accurate.

- Interoperability/IFC Support measures the degree to which data can be reliable exchanged among software applications using the open-standards

Table 2.17 - Interoperability/IFC Support CMM (Source: NIBS)

Maturity Level	Interoperability/IFC Support
1	There is no Interoperability between software programs. Information is reloaded for each application.
2	There is some Interoperability but it is not automatic or seamless. Information may be cut-and-paste at this level of maturity.
3	There is some machine-to-machine flow of information but it is not common or the norm; it is still the exception.
4	Information is flowing between COTS products, often by using products from the same vendor. The interfaces are likely proprietary.
5	In this level of maturity, information is transferred between COTS products typically from the same vendor, but not all applications are supported.
6	There are good machine-to-machine linkages at this level of maturity and information Interoperability is the norm.
7	IFC are used on a limited basis for Interoperability with some software packages.
8	IFC use is becoming more commonplace yet is still less often used than other approaches.
9	IFC use is the norm, but not exclusively used to attain Interoperability. 70% - 90% IFC-based Interoperability.
10	At this level of maturity, IFCs are fully implemented and used for interoperability.

3
CONSTRUCTION MANAGEMENT AND BIM

Associated with construction and project management are many tasks that can be done more efficiently when aided by BIM technologies.

To some companies, using BIM during the construction phase may mean implementing a new process and refining operational tasks. Although some companies use BIM throughout the entire course of a project, many others either stop using it in the preconstruction phase or use various bits and pieces of a BIM process to help them better coordinate a project. Despite there is no right or wrong way to use BIM, the most important question is, how improvement can be achieved in the way construction management is done? As projects progress, it is easy to slip back into the same old way of doing things, and in doing this, there is very little chance for future growth, either in technology or in efficiency. Gradually adopting BIM initiatives is the best way to change existing practices until it becomes habit. As project become more advanced, complex, and difficult, the technology used in these projects will also advance along with them. More exciting, the construction industry is driving these technologies further than ever before. Entrepreneurs, software companies, and tech-savvy professionals are developing BIM tools rapidly to meet the rising demands of the industry [17].

3.1. BIM AND CONSTRUCTION ADMINISTRATION / MANAGEMENT

As the BIM industry continues to develop architectural and engineering modelling tools, is critical to understand that BIM provides contractors with more effective ways to perform their work and more ways of finding and coordinating the model and project information. Considering this is also critical that software companies learn how contractors are using BIM and what they would like to see more of, and start targeting that market.

Contrarily to the misconception that BIM doesn't work in the field and that it isn't completely intuitive and integrated, should be stated that in fact despite difficulties and some barriers still extant BIM does "work" in the field as shown in the case studies of these work and many others. In the field, BIM may be used to do the following tasks, some of them addressed in more detail further on:

- Produce digital RFI;
- Produce and manage project information associated to the bim;
- Perform 4D scheduling updates;
- Create a field sequencing clash detection;
- Clarify the installation of fabricated components;

- Add as built and in field model information;
- Run field clash detection reporting;
- Use of BIM for check/punchlists;
- Prepare the model for project closeout;
- Commissioning and Handover process.

Through the use of BIM contractors and construction managers are able to avoid, predicted, and react better to issues, achieving a better productivity by reducing rework and increasing efficiency of the overall project. Although BIM brings many advantages, it is not able to eliminate all uncertainty associated to the constructions activities, as previously stated. For that reason, some issues will need to be dealt with in the traditional way, resolved by the team as the project moves forward with a mind-set of flexibility.

In the traditional process, only after 100 percent of the construction documentation and addendum and revision information have been turned over to the contractor, construction begins. It's the contractor's responsibility to verify that the immediate information needed is adequate and the most recent. Further issues for the project need to be identified and put on a path of resolution for all scopes of work. To do the documentation verification contractor analyses and overlays CAD files or sheet drawings, this is a time-consuming task lacking visibility, and prone to errors and missing information [17].

Opposing to the traditional process, with everything modelled and files compiled into a composite model, BIM makes easier the verification of design changes and comparison between trade models, through clash detection, sequencing, or deviation reporting more efficiently. However, likewise CAD, the process to update, review and test the models is a time-intensive effort. While in CAD these time was spent in non-value adding tasks like sorting through the information trying to identify issues, in BIM the time is spent coordinating and reviewing all of the issues found by the analysis tool between the revised models.

3.1.1. Trade Coordination & Clash Detection

Besides juggling the schedule, managing the budget, sorting through constructability issues, and managing relationships, is other major responsibility of the construction manager to coordinate the multiple trades associated to the project

In the past, the coordination was made, as previously stated, by overlaying 2D drawings in a time-consuming task. In reality the only way to accomplish a useful coordination model, is through a composite model in which all files are 3D, linked and endowed of intelligent throughout the design phase.

Using clash detection tools to coordinate trades is one of the areas where BIM really shines, captivating a growing acceptance and adoption. The degree of accuracy and the ability to layer multiple data sets and models into one file and run a clash analysis producing reports, are new in the construction industry equipping construction team with the ability to perform a more effective and productive work.

Clash detection tools, like Navisworks (appendix A – page XV), allow users to run entire models against other models to see what the scope of interference is. Virtually anything in the model can be tested against another set of objects, elements, or selection criteria for clashes (Figure 3.1). As the number of reported clashes diminishes, the areas that are being tested can be narrowed down; they can be avoided if there are known issues that are to be resolved later in the project timeline [17].

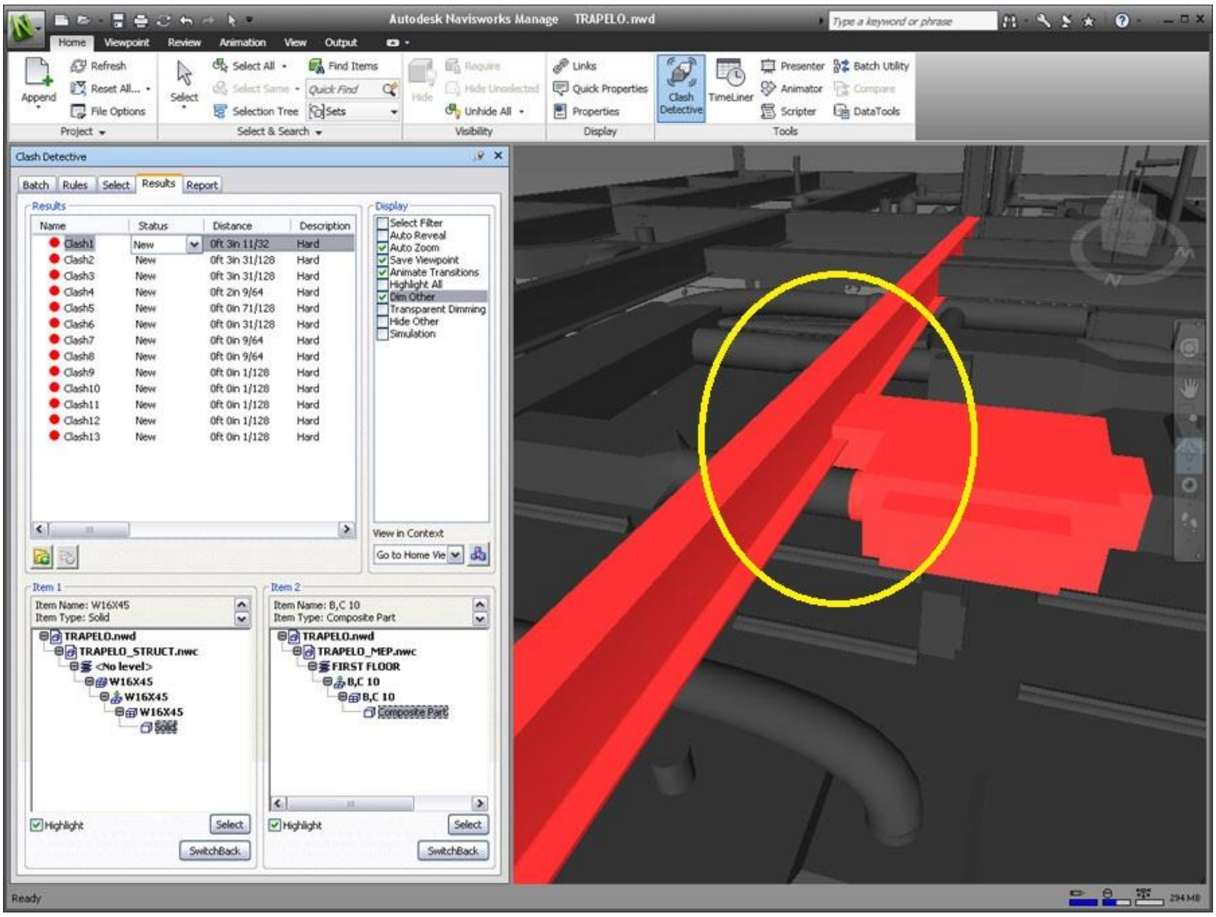

Figure 3.1 - Navisworks performing a Clash Detection (adapted from [18])

3.1.2. BIM AND PUNCHLIST

In its simple form, BIM is a database of information represented by three-dimensional objects yet at its root is still a database, enabling this way the link between the database information and specific punchlist [17].

With the currently available tools able to streamline processes and embed puchlist information within the BIM model, punchlists are other of the interesting areas of BIM. Using mobile devices, construction management personnel is able to complete the most updated puchlist while in the field providing detailed information about the punch items in a more productive way. Today there some available options to track and log these items:

- Creating custom space schedules in a modelling software like Revit [17];
- Using software such as Acrobat to create specific markups within sheet and model files [17];
- Using Navisworks or similar software to automate numbering and directly host comments to parametric objects for review [17];
- Using plug-in or export software that allows users to see an exported or linked version of the BIM to be tied to external software that hosts comments [17];
- Using BIM field data management tools, like BIM 360 Field, to process, archive, report and organize punchlists (further developed in this chapter).

3.1.3. BIM CONSTRUCTION ANALYSIS AND PLANNING

Construction planning and scheduling involves sequencing activities in space and time, considering procurement, resources, spatial constrains, and other concerns in the process [8]. Intended to facilitate this job and enable users with the ability to perform a line of balance scheduling (Figure 3.2), specialized software packages better suited to the building construction like Vico Control part of Vico office Suite (appendix a – page XII) are being developed.

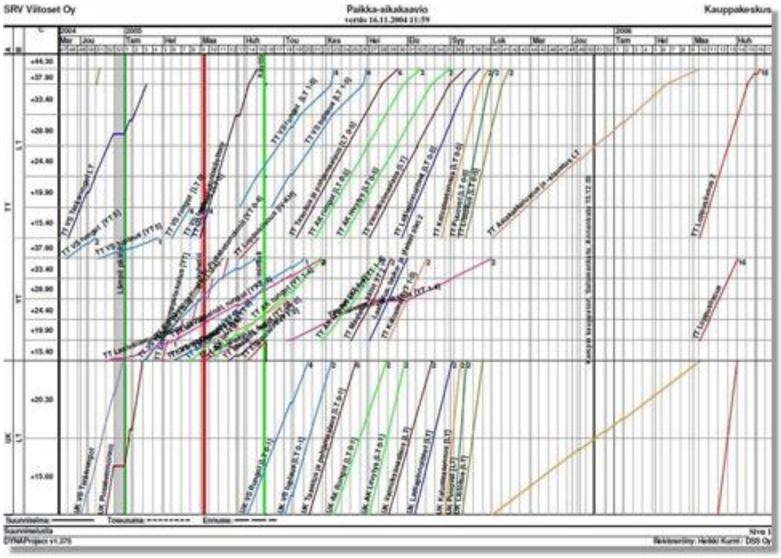

Figure 3.2 – Flowline chart, line of balance scheduling [19]

At the same time BIM allows schedulers to create, review, and edit 4D models more frequently, which has led to the implementation of better and more reliable schedules.

Contractor can use 4D simulations with various intents, as a communication tool for revealing potential bottlenecks and as a method for improvising collaboration ensuring that the plan is feasible and efficient as possible. Associated to 4D models and simulations some benefits are presented below:

- Communication: Planners can visually and communicate the planned construction process to all project stakeholders. The 4D model captures both the temporal and spatial aspects of a schedule and communicates this schedule more effectively than a traditional Gantt chart.
- Multiple Stakeholders Input: 4D models are often used in community forums to present to laypersons how a project might impact traffic, access to a hospital, or other critical community concerns.
- Site Logistics: Planners can manage laydown areas, access to and within the site, location of large equipment, trailers, etc.
- Trade Coordination: Planners can coordinate the expected time and space flow of trades on the site as well as the coordination of work in small places.
- Compare schedules and track construction progress: Project managers can compare different schedules easily, and they can quickly identify whether the project is on track or behind schedule.

The planning and scheduling process depends on the tools used, in the BIM handbook [8] some issues and recommendations are presented that any planner should consider:

- Level of detail: The level of detail of the model depends and is affected by size of the model, critical items need to be communicated, and the level of information needed to schedule activities. A Planner can decide to represent a wall as a single component because the critical issues are sequencing the floors or wall sections, not the wall system's sequencing of installation, while a sophisticated structural earthquake system, may require a more detail model for each installation step, and a foundation footing for example may require multiple extra activities like excavation, forming, placing rebar, curing concrete, and stripping forms.
- Re-organization:4D tools often allow scheduler to re-organize or create custom groupings of components or geometric entities. This is an important feature because the way that the designer or engineer organizes a model is not usually sufficient for relating components to activities. This is critical for developing and supporting a flexible and accurate 4D model.
- Temporary components: The building model should reflect the construction process so that even temporary structures, excavations details, and other features that exist during construction can be shown in the 4D simulation, in order to enable a visualization of what will influence spatial constrains for people and equipment.
- Decomposition and Aggregation: Objects shown as a single entity, such as a slab, may need to be broken into portions to show how they will be constructed. Another issue that planners face is how to break up specific components, such as walls or roofs, that a designer or engineer would model as a single component but planner would divide or break-up into zones. Most specialized tools do not provide this capability, and the planner must perform these "break-ups" within the 3D/BIM tool.

3.1.4. Quantity take-off and Cost Estimating

Provided with the capability for extracting counts of components, areas and volumes spaces, and material quantities (Figure 3.3), BIM quantity take-off tools enable a quicker extraction of more detailed spatial and material quantities information directly from the bim , and the production of approximate cost estimates.

For more accurate cost estimates prepared by contractors, problems may arise when the definition of components is not properly defined and the quantities needed for cost estimating are possible to be extracted. These problems can be address, but the approach depends on the specific BIM tool and associated estimating system.

Although quantity take-off tools provide accurate reports of the components quantities, they are not replacement for estimations. In order to produce a valuable and accurate estimate, estimators need to asses beyond the quantities, the specific conditions of each project that impact cost, such as unusual wall conditions, unique assembles and difficult access conditions. The automatic identification of these conditions by any BIM tool is not yet feasible.

To fully leverage BIM, designers and estimators will need to coordinate methods to standardize building components and the attributes associated with those components for quantity take-off. In addition, in order to generate accurate quantities of sub components and assemblies, such as the studs inside a wall, it is necessary to develop standards for these assemblies.

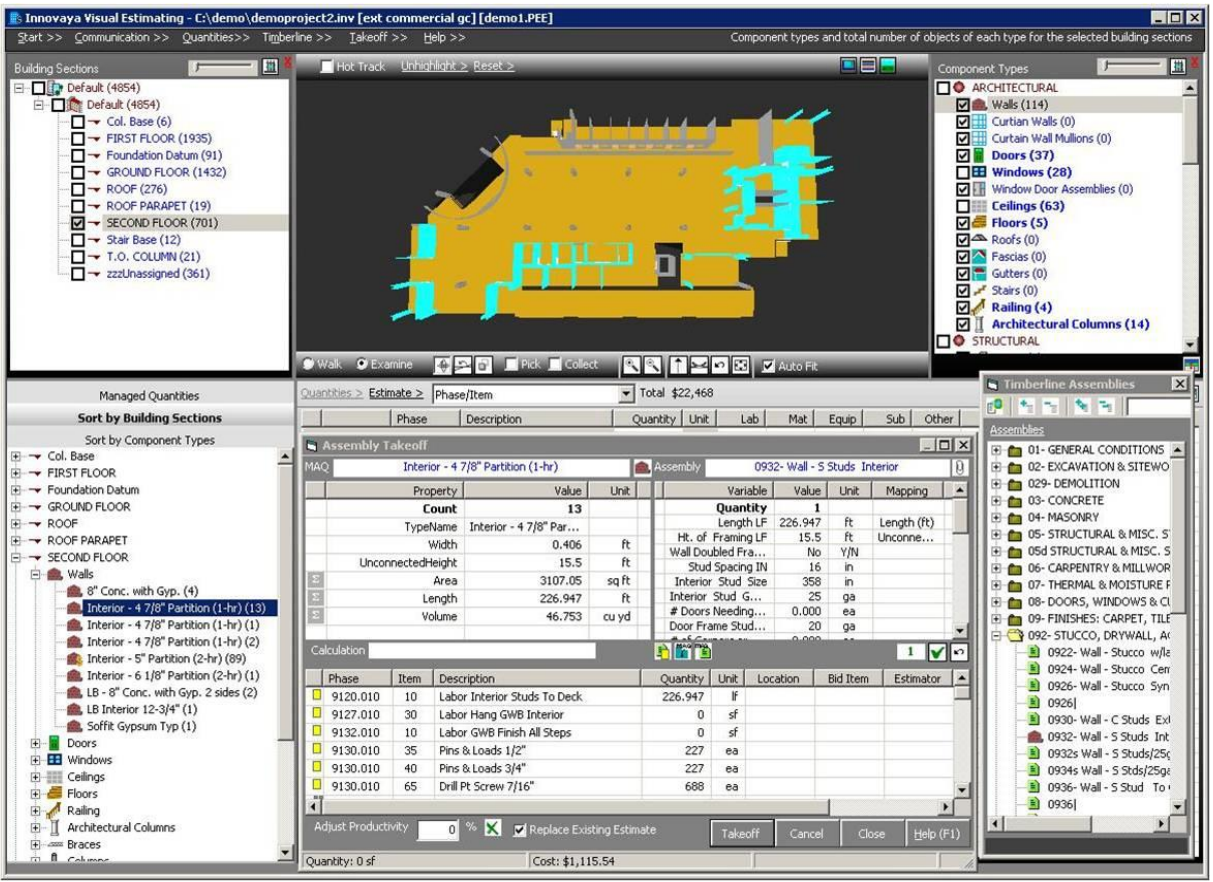

Figure 3.3 - Innovaya Visual Estimating screenshot (appendix A – page XVII) [20]

3.1.5. BIM ON SITE: VERIFICATION GUIDANCE AND TRACKING OF CONSTRUCTION ACTIVITIES

Automated data collection technologies (ADCT) in construction can be used to compare the actual construction conditions against the model searching for possible human errors in the installation, catching these errors as they occur or as soon as possible has great value. Sophisticated techniques are evolving to support field verification, guide layout and track installation, like the following:

- Laser scanning technologies: Contractors can use laser technologies, such as laser measurement devices that report data directly to a BIM tool, to verify that concrete pours are situated in exactly the correct location or that columns are properly located. Laser scanning can also be used effectively for rehabilitation work and capturing as-built construction details [8]
- Machine-guidance technologies: Earthwork contractors can use machine-guided equipment to guide and verify grading and excavation activities driven by dimensions extracted from a BIM [8].
- GPS technologies: Rapid advances in GPS and the availability of mobile GPS devices offer contractors the ability to link the building model to global-positioning-systems to verify locations [8].
- RFID Tags: Radio Frequency Identification tags can support the tracking of component delivery and installation onsite. BIM components that include references to RFID tags can automatically update with links to field scanning devices and provide contractors with rapid feedback on field progress and installation [8].

- Mobile data collection devices (Tablet PCs): With the mobility of tablet PCs the information can be collected, updated and accessed automatically by the users where and when needed.

These ADCT involve minimum human input, focusing their areas of application in, monitoring production storage, delivery, installation and quality control of components; supporting the erection/installation of components; and providing lifecycle information about components and their performance.

Reducing waste and enhancing visibility of supply chain network, these tools create cost savings through quality improvements, reducing the quantity of missing and incorrectly shipped components, and time reductions, and time reduction, by reducing activities duration, resulting in less labour cost.

Associated to these ADCT are the field data management tools FDMT, like BIM 360 Field presented in the next section.

3.2. BIM 360 FIELD – OBJECT OF STUDY

BIM 360 Field is a software through which a company can overcome the bridge between office and site activities, taking advantage of mobile devices, BIM, wireless connections and 3D model visualisation, it is a Field BIM data management platform.

In June of 2012, Autodesk acquired the Vela from Vela Systems, a software development company that have a portfolio composed by a series of FDMTs. The FDMTs allow project information to be recorded in the field and automatically updated to a central database, and then communicated with project /construction managers, as well as all project participants. When acquired, Autodesk changed the name Vela to BIM 360 Field in order to incorporate it into their BIM 360 Package. The BIM 360 Packaged is composed by some Autodesk BIM software, and all of them are provided as a Software as a Service (SaaS), some examples are: BIM 360 Glue (appendix A – page XI); InfraWorks 360; Simulation 360; 360 Energy Analysis for Revit; Green Building Studio; 360 Structural Analysis for Revit; and 360 Rendering.

As showed in Figure 3.4, BIM 360 Field, serves as a central hub for construction information flow between all project participants. Simultaneously, is presented, for each of them, the information input/output and it connection to the software modules.

Regarding the coordination flow with the use of BIM 360 Field there is no major change to the traditional approach, with the owner coordinating with the contractor and A\E, and the contractor simultaneously coordinating with the A/E and Sub-Contractors. BIM 360 Field brings a simplification of the process, due the eased access to better organized information.

BIM 360 Field is able to store all project data in a specific log, in the cloud accessible to all stakeholders, automatically compiling the information into useful reports. These reports can be used to analyse delays, RFIs, punchlists items, and rework. At the same time BIM 360 Field organizes all project data and provides a way to classify the information accordingly to its use. In order to do this in an efficient way and in an easy to use interface, BIM 360 Field is divided and organized in five different modules, listed below and described further:

- Material and Equipment Tracking;
- Quality and Safety checklists;
- Issues Tracking and Notification;

- Commissioning and Handover;
- Documentation Management.
- Tasks Schedule

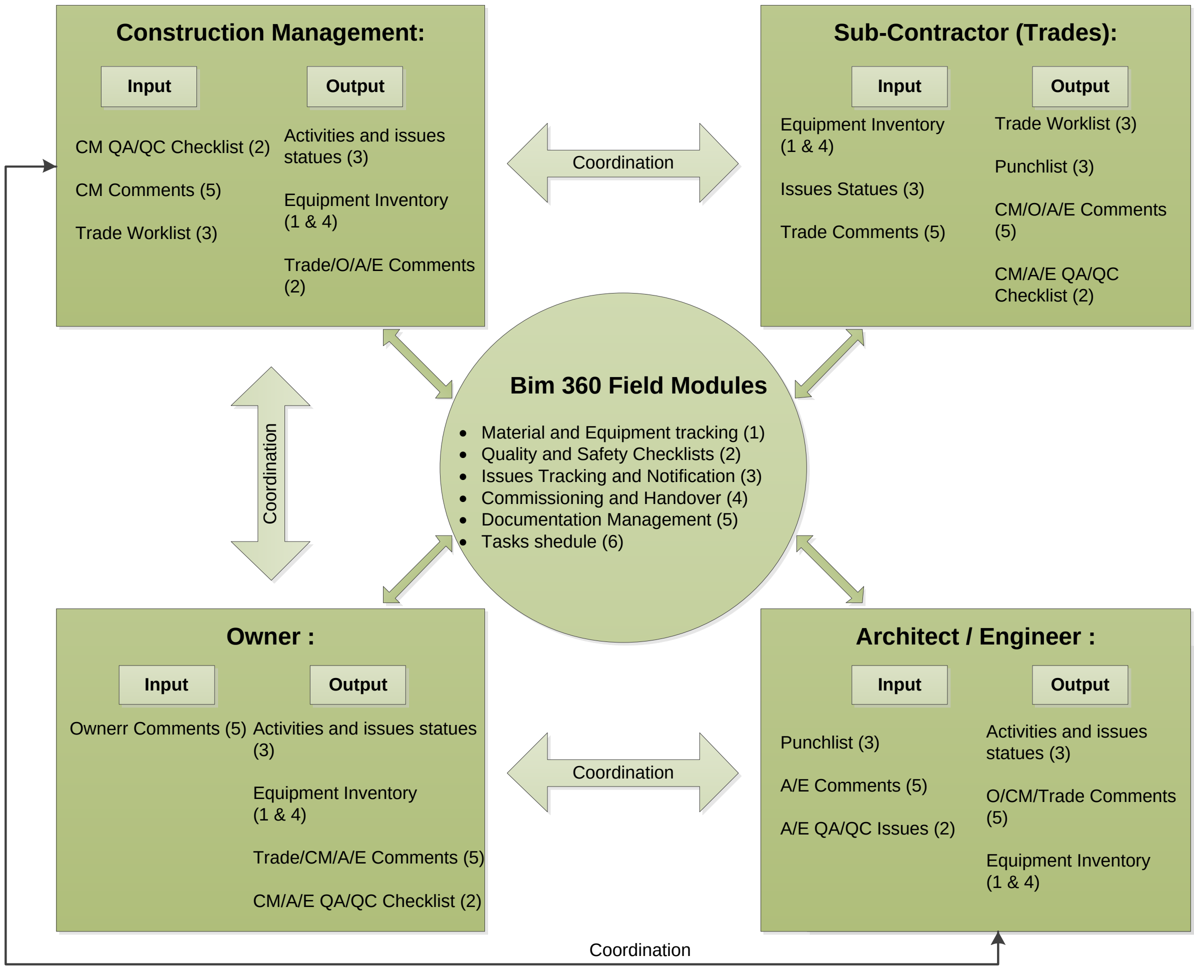

Figure 3.4 - Flowchart of BIM 360 Field inputs and outputs in relation to project team members [21]

3.2.1. Material and Equipment Tracking

With bim 360 field material and equipment tracking module an increase of accuracy and quality is achieved by eliminating double work, and automating certain tasks.

Fitting equipment and materials with electronic identification (RFID, barcode) linked to a corresponding equipment list in the software and consequently to the bim, these can be tracked, and the corresponding details (status, checklist, to-do list, etc) are automatically accessible.

Furthermore, considering the previously stated connection, the particular status of the items can be tracked using colour identification, a “heat visualization” of the real-time progress.

The flowchart diagram in Figure 3.5 shows a comparison between the existing method and BIM 360 Field enable RFID method for tracking materials and equipment items. Tasks 2, 3, 6 and 10 are substantially shortened by using Vela due to near-instant identification and status updating on the iPad. Inspection and verification tasks 4 and 7 will have a higher chance of success since using RFID tags is a more

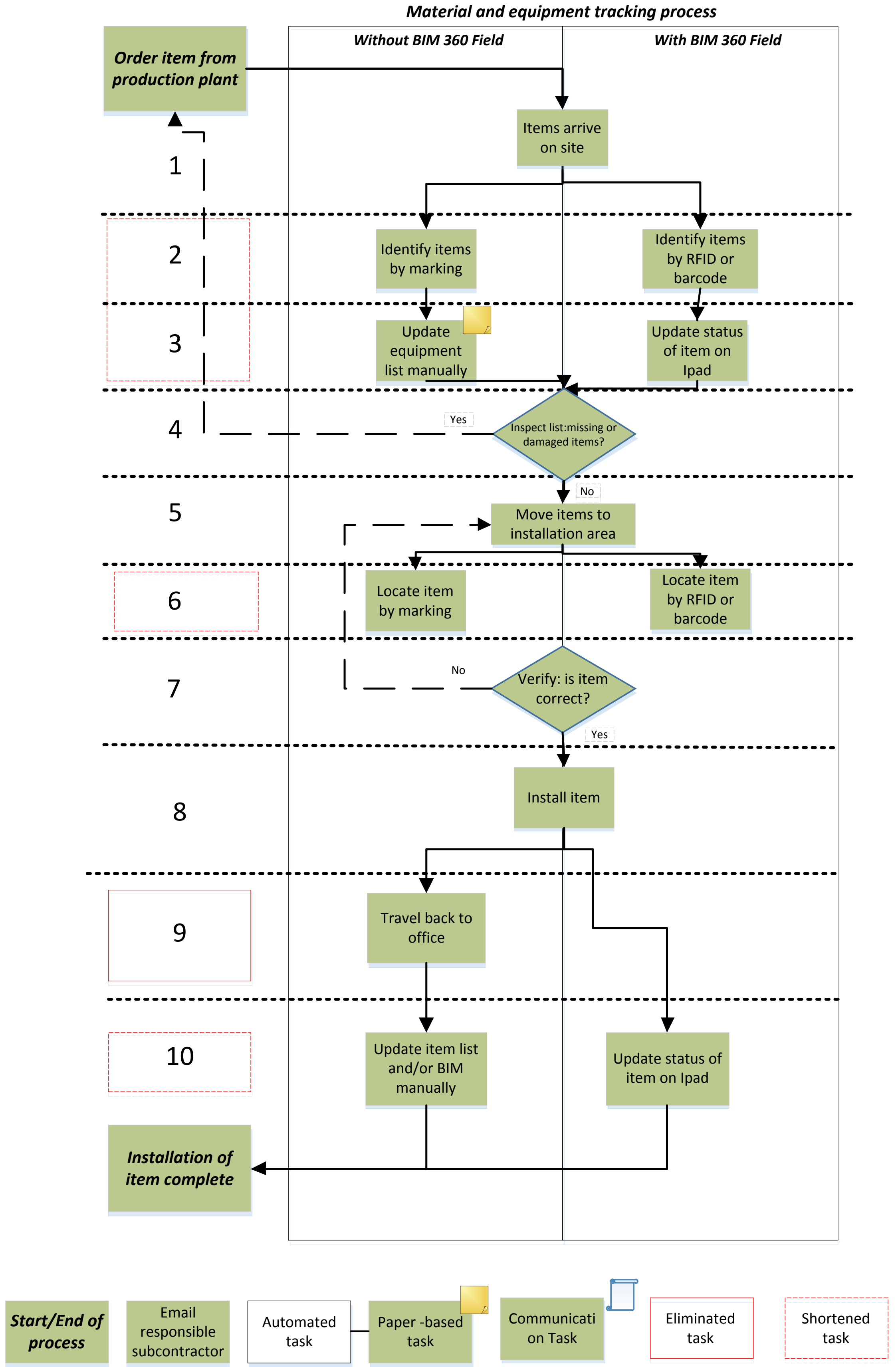

Figure 3.5 - Flowchart diagram showing tasks in material tracking process [22]

accurate and reliable way of correctly identifying equipment. Task 9 is eliminated altogether, as all updating happens on site. The combined efficiency and accuracy of the Vela and RFID/barcode method result in a shorter process with a higher quality result.[22]

The connection between the software and the model proves useful in commissioning and handover of building systems in the final close out stage of a project. Mobile technologies can be used to record accurate data in the field which can then be used to set up a facility management system.

3.2.2. Quality and Safety Checklists [22]

Checklists for quality and safety inspections can be created in BIM 360 Field and saved in a common library in the cloud, from which they can then be accessed by construction managers, distributed to the assigned users, and filled out on tablet PCs anywhere. As checklists are completed on site, any non-affirmative answer will automatically prompt an issue to be created (Figure 3.6), which can then be filled out with details and aggregated into a central master list of project issues.

The standardization and easy accessibility of checklists saves time and reduces the possibility that a requirement will be overlooked during an inspection. A record is also made of inspections as they occur, making the verification that they are occurring at the right frequency possible.

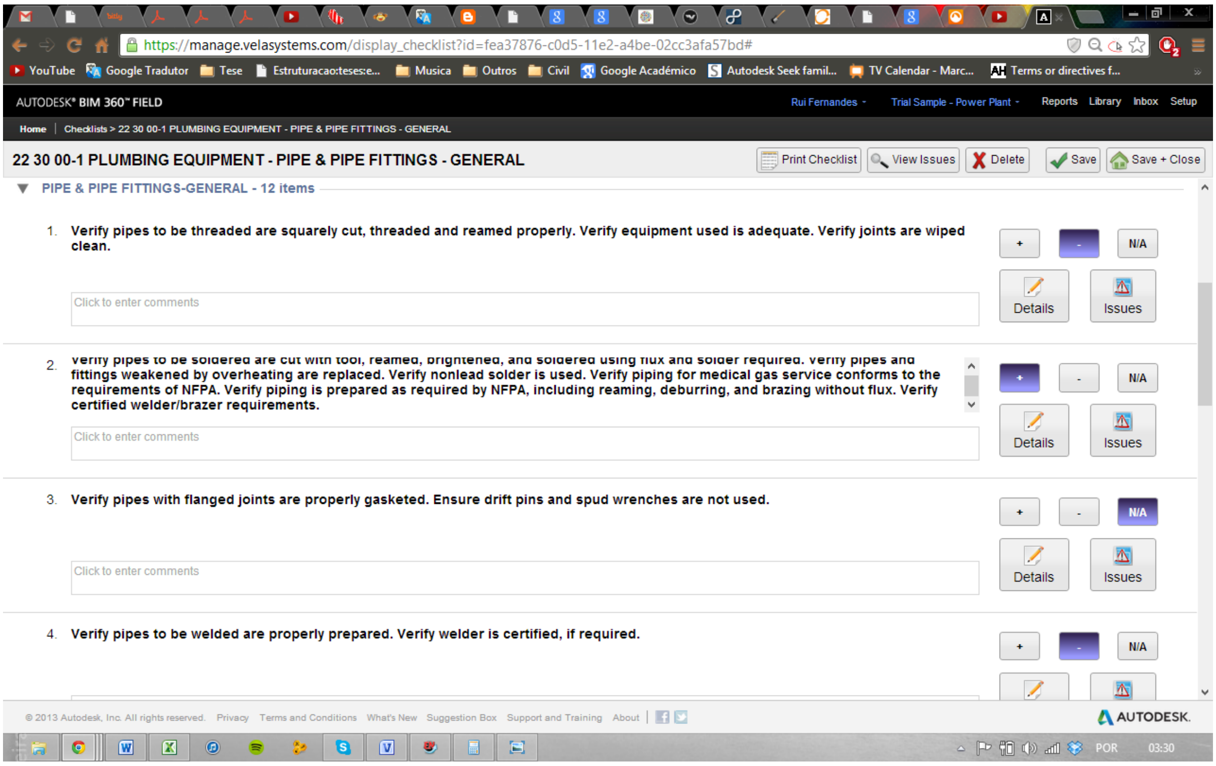

Figure 3.6 - BIM 360 Field Checklist

3.2.3. Issues Tracking and Notification

When an issue is identified in the field, users can add it to an existing database of issues stored on the project server. The process of notifying a the party responsible for the issue is illustrated in figure 3.7, and compared to the pre BIM 360 Field base case to illustrate how several tasks are shortened, automated or eliminated altogether, saving substantial amounts of time in the process. Step 1 is now standardized, as users simply press: create new issue to bring up an issue template. If a photo is attached in step 2, it can be directly marked up and annotated on the iPad. Steps 3 and 4 in the base

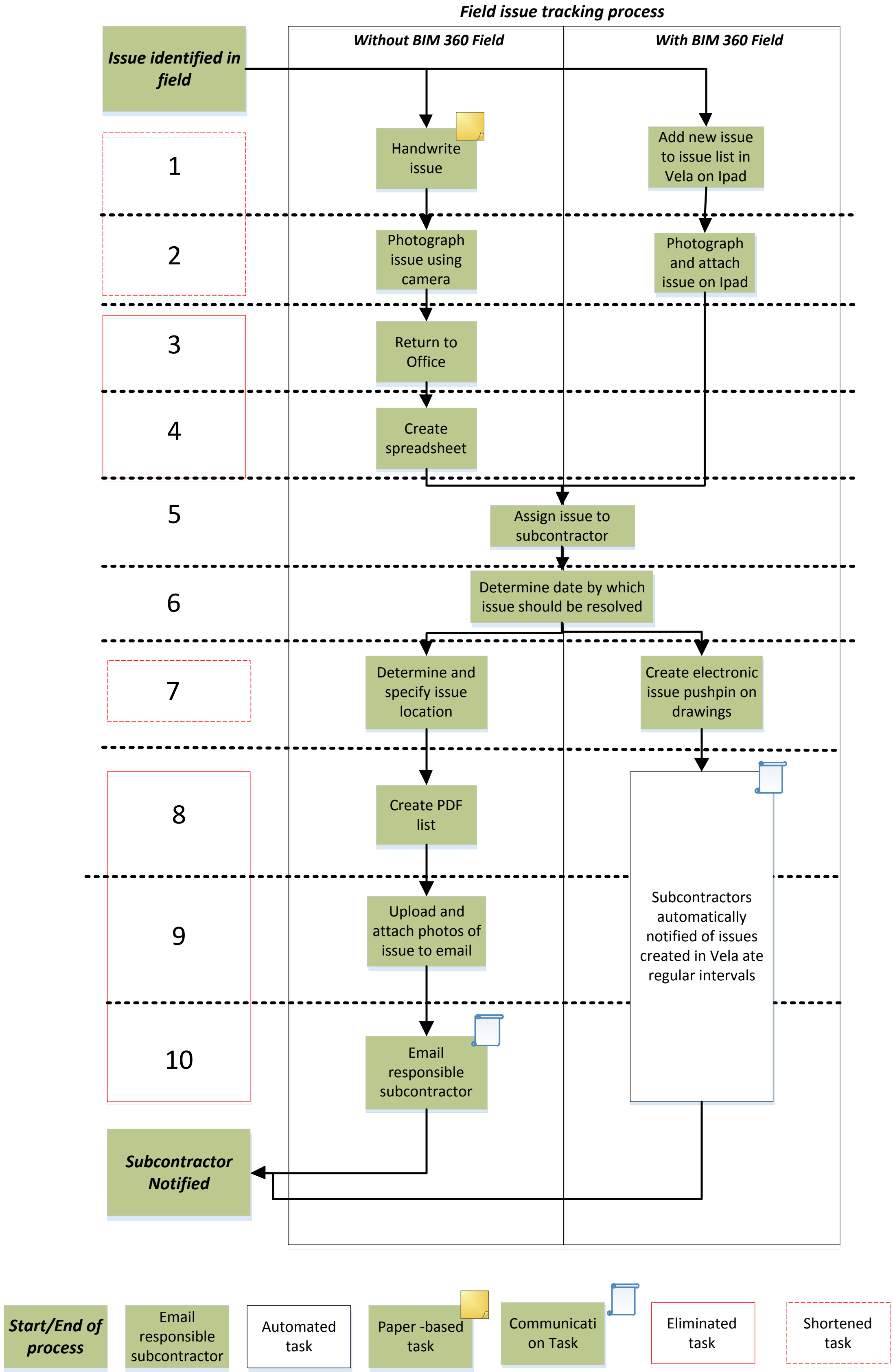

Figure 3.7 - Flowchart diagram showing process of notifying sub-contractors of issues [22]

case are eliminated altogether using BIM 360 Field, as users no longer have to return to the office and create spreadsheets to record issues on the central project server. Step 7 is also standardized, as users can now drop electronic pushpins onto digital plans and the model to indicate the exact location of an issue to any viewer of the plans. BIM 360 Field then sends regular automatic notifications to subcontractors, notifying them of their new and outstanding issues, thus removing the need for steps 8, 9 and 10 [22].

Once an issue is communicated to a subcontractor, it must then be resolved (see figure 3.8). BIM 360 Field also considerably reduces the tasks involved in the process of identifying issues and communicating their resolution back to the general contractor or inspector. With BIM 360 Field, subcontractors with tablet PCs, or through mobile electronic plan stations provided by the contractor, can view their own issues, and each item with an associated pushpin on digital drawings can be clearly located as shown in task 1. Once the appropriate action has been taken and the issue resolved, the responsible subcontractor can simply change the status of the issue in BIM 360 Field, for instance, from 'open' to 'ready for inspection', thus eliminating tasks 3 and 5 and automating task 4 [22].

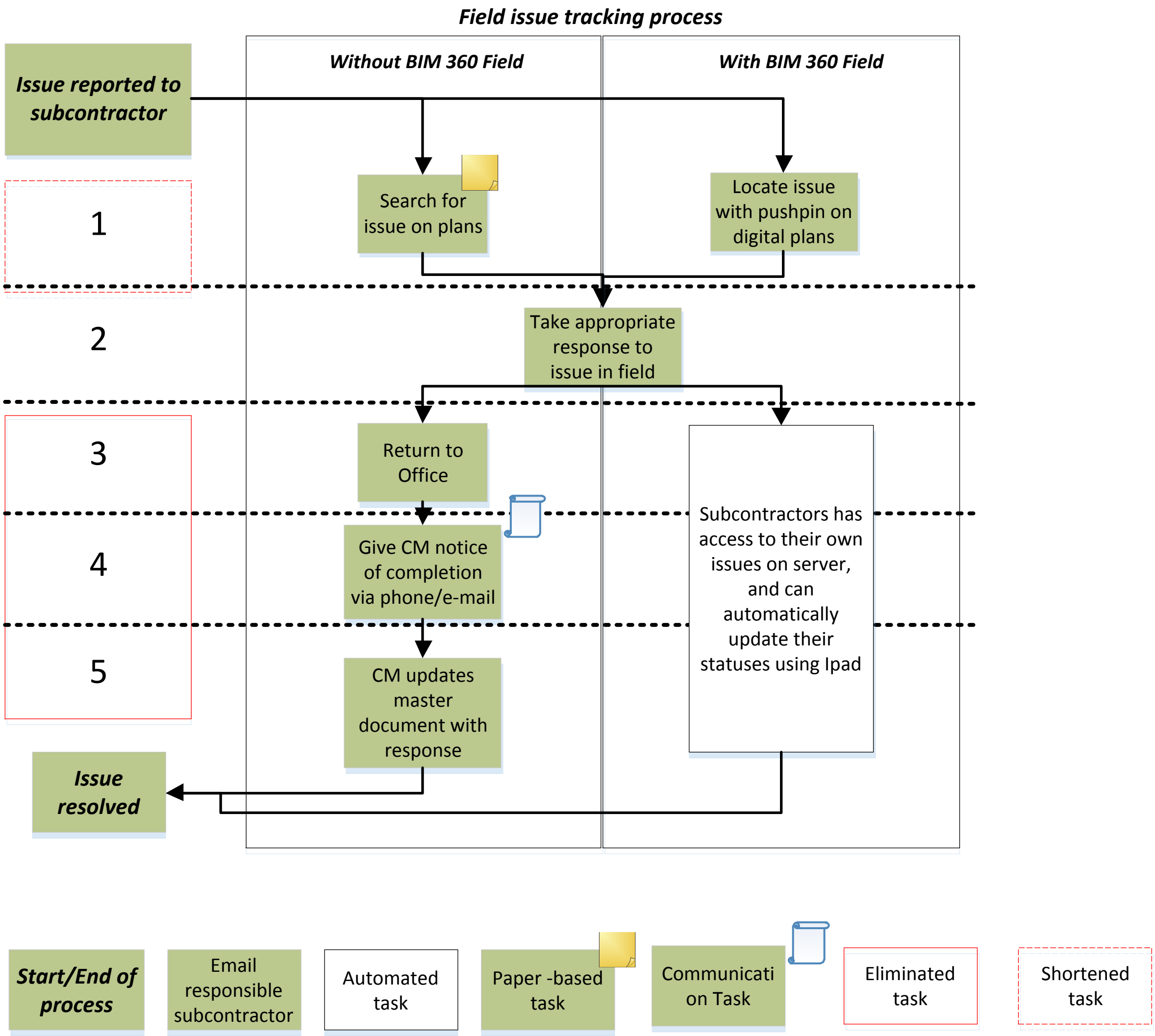

Figure 3.8 - Flowchart diagram showing tasks in process of communicating responces to issues [22]

Additionally, by logging issues and saving them in the cloud, BIM 360 Field creates a clear data trail for issues making more difficult for them going ignored and unresolved, providing at the same time risk mitigation for time sub-responsibilities disputes.

Finally, because issues are logged, analytic data can be viewed for a variety of matters regarding quality issues, such as which subcontractor has the most outstanding, the rate of resolving issues, etc. This can be used to compensate or penalize parties based on their performance, and incentivize quicker responses to issues. Data from multiple projects can also be compared by executives for cross-project performance reviews.

3.2.4. Commissioning and Handover .[23]

Unlike traditional paper-based systems, the Commissioning solution of BIM 360 Field, captures all system and equipment information electronically, right in the field, which saves time and reduces errors. Dynamic reporting shows the statuses of all systems and equipment, enabling commissioning agents and other responsible parties to better manage project status.

Commissioning information and linked documents from Autodesk BIM 360 Field can be the handover deliverable to the owner for handover and facility operations. There are two options in this regard:

- BIM-based handover: Provide a "Handover model" that includes key systems and equipment data (e.g., warranty start dates) as well as key documents. The owner can use this model for on-going document access and even update it to create an "as maintained" model for Operations.
- COBie2 or other file-format based handover: File-based commissioning information can be handed over to the owner in a variety of structures and formats, including COBie2 in Microsoft Excel, .xml or .ifc.

3.2.5. Documentation Management

The Documentation management module automatically delivers project documents to all company and team members, guaranteeing the right information is delivered to the right people. Field superintendents, project managers, safety managers, subcontractors, and their teams get access to the most up-to-date documents, plans and specifications in BIM 360 Field. To distribute documents is only needed to update the latest project documents into the software library and they will be immediately available to everyone on the team.

3.2.6. Tasks Schedule

Tasks software allows user to schedule work for team members to complete at specific dates and times. For example, assign safety manager a task to complete a safety inspection walk at 11:00 AM on a coming Friday. Or subcontractors might use tasks to request inspections of work they've done. When there are multiple steps involved with a task, simply change the assignee to the next person in the process once a step is complete. Task authors and assignees receive notifications when a given task status changes so construction manager can keep track of everything that's going on. [23]

3.2.7. Training and Short Term Efficiency Loss

Directly associated with the adoption of a new software, and the consequently change in workflows, is the need for training. BIM 360 Field is no exception and derived from that training exists a temporary efficiency loss as can be seen in figure 3.9. As users learn how to effectively operate the new working method, efficiency grows, surpassing the previous level of efficiency.

Regarding BIM 360 Field training is also important to point out that Autodesk can provide on-site and online training, nevertheless there's still the need to designate someone to continue providing training.

In the James B. Hunt Library Project [21], Vela provided two days of on-site training an online training as part of the paid service, despite that, the construction company still have to designate two construction managers trainers dispending between 2 to 4 hours weekly training the staff.

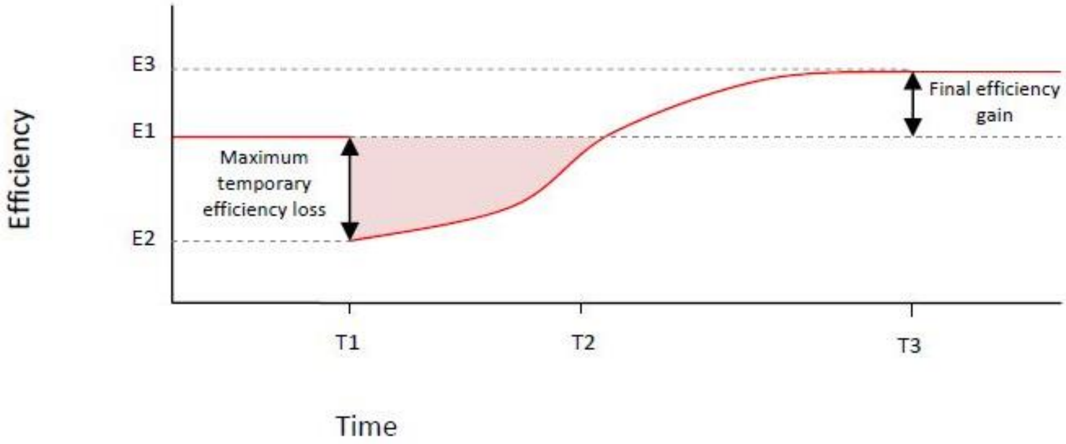

Figure 3.9 - Temporary Efficiency Loss [22]

4
CASE STUDIES ANALYSIS

4.1. INTRODUCTION

Throughout this chapter, it will be presented in sub-chapters a series of BIM 360 Field case studies like Table 4.1 shows. The objective of this chapter is to show the different modules of BIM 360 Field, how they are used by different organizations and in different delivery methods. At the same time showing how the use of BIM 360 Field can help solve a vast array of day to day construction challenges, as well as the benefits associated to its adoption.

Table 4.1 - Case Studies

Sub-Chapter	Case Studies
4.2	CMC Group : Grovenor House, Miami FL [24]
4.3	William A. Berry & Son [15]
4.4	Suffolk Construction: Liberty Hotel, Boston MA [15]
4.5	Robins & Morton: Florida Hospital Memorial Medical Centre [25]
4.6	Balfour Beatty Construction [26]
4.7	Barton Malow: Maryland General Hospital [27]
4.8	Barton Malow (Autodesk Navisworkss, Revit & BIM 360 Field) [28]
4.9	Consigli Construction Co., Inc. (Autodesk Navisworks & Revit) [29]

In order to accomplish that, some case studies are about specific projects like 4.2, 4.4, 4.5, 4.7, 4.8, and 4.9 where the adoption of the software has solve specific challenges to those projects, case studies like 4.3 and 4.6 that address the company wide adoption of BIM 360 Field. In Each of these case studies BIM 360 Field software is used with different purposes as shown in Figure 4.1, highlighting the benefits of each of them.

The case studies are firstly presented one in each sub-chapter and after their presentation, in sub-chapter 4.10 is done one analyse and discussion of results. The main objective of this sub-chapter is to present in a qualitative way the main benefits of BIM 360 Field observed in the case studies. Although some of the case studies might seem to address the same issues and benefits, they are associated to different backgrounds which gives them add value in the conclusions.

For a good understanding of some case studies there is a need to explain two points. Most of these case studies where done before Autodesk acquired Vela Systems and renamed it to BIM 360 Field in

11 of June of 2012, so it will be obvious that in citations people address to BIM 360 Field as “Vela” or “Vela Systems”. Also the last to cases despite talking about BIM 360 Field they are about the relation between different BIM software and are presented here for that reason, to call attention to the benefits of a major BIM application to projects.

	RFI	Worklist	PunchList	QA / QC	Safety	Commissioning	Tasks	Documents	Reporting	Subcontractor Management	Field Mobility
4.2		x	x	x	x		x		x	x	
4.3						x					
4.4	x				x					x	x
4.5			x	x	x			x	x		
4.6	x		x	x	x	x				x	x
4.7						x					
4.8						x					
4.9		x	x			x					

Figure 4.1 - BIM 360 Field Modules and Case Studies relation

After the discussion of results in sub-chapter 4.10, in 4.11 are presented some of the results of Michael Moran Master Thesis [22] where he does a study about the use of BIM 360 Field in 15 Skanska projects and grounded in data taken from those projects and interviews with construction management staff using BIM 360 Field, present some of the software benefits in a quantitative way. This sub-chapter serves as a data validation to some conclusions taken from the case studies presented in this work.

4.2. CMC GROUP : GROVENOR HOUSE, MIAMI FL

The CMC Group is a premier South Florida Builder, focused on providing high-end, high-value properties. With the Grovenor House (Figure 4.2), a 30 story high-end condominium project in Coconut Grove, Florida; the CMC faced a challenge. Due to the significant time-to-close pressures in a competitive selling market and the 166 luxury units that required a high degree of finish detail, the quality assurance and control (QA/ QC) was an essential aspect of the project.

In order to meet and maintain these high standards of quality the CMC team had to find a way to more efficiently create, analyse and manage work-to-complete and punch lists. With the replacing of field notebooks with tablet PCs and introducing BIM 360 Field (former Vela Systems) Worklist/ Puchlist software module CMC was able to maximize team efficiency by saving time and improving project quality monitoring, as explained by Rick Pena Grovenor House Project manager:

“*After walking the job site I used to spend at least two hours typing up my notes into the computer so I could track issues and task the subcontractors. With Vela (deposition taken before Vela Systems was acquired by Autodesk), I was able to add field notes and issues while I was in the field, saving hours of time. And it was easy to use – most of my common problems were already in the system and could be reused with a tap of a pen on the screen.”*

Rick Pena also highlights other two points where BIM 360 Field was a winning bet. The automatic reports software module of BIM 360 field which unlike the normal time consuming process of formatting and printing reports, allows the user to easily generate task lists by subcontractor, floor, room, section, and even by specific issue description.

"For example, we would give a sub a list of all locations in the building with a specific problem, such as shower glass opening hold-to dimension, and the sub would then task their team to only do that work. Vela made the whole project more efficient in how we managed our resources"

Figure 4.2 - Grovenor House [30]

And the BIM 360 Field Owner Handover and Customer service software modules, that allow the CMC customer service team during the walkthrough to log the owner punch items on the tablet and assign tasks to the subcontractors immediately and print out work lists, which improve the efficiency of the closeout process and help deliver premium customer service.

In summary, the application of BIM 360 field to this project created time gains resulting in the end of construction and Owner Handover approximately four months earlier, as well as cost savings in the project. BIM 360 Field created these time gains and cost savings by:

- Enabling the team to record and track information in the field, eliminating manual transcription;
- Generating key reports automatically instead of via spreadsheets;
- Providing new ways of organizing quality issues that improved subcontractor efficiency.

Concluding with the words of Rick Pena:

"By using Vela Systems software for construction, punch, and owner walkthroughs, CMC compressed the project timeline, improved visibility into quality of the work, and provided a very high level of professionalism during the process."

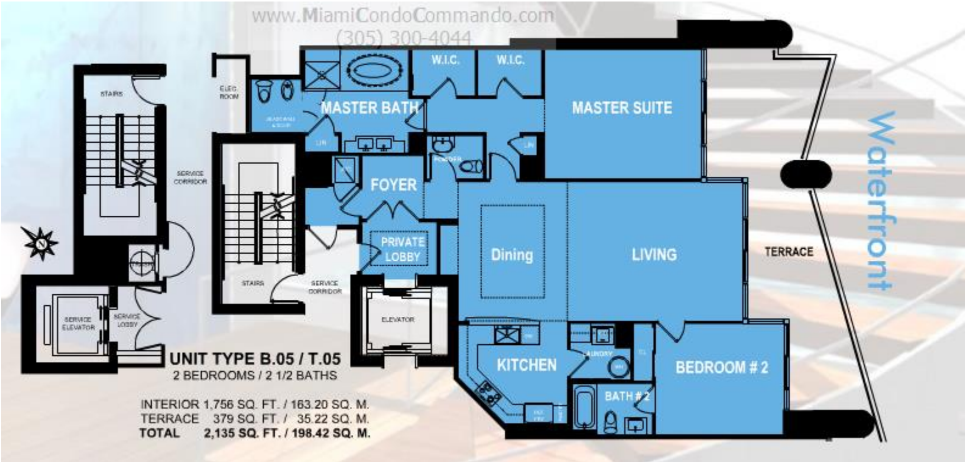

Figure 4.3 -Grovenor House, Floor 17 to 26, Unit type B.05 / T.05 Master Plan [31]

4.3. WILLIAM A. BERRY & SON

One of the oldest construction companies in North America founded in 1857, and a well-respected global construction management firm. William A. Berry & Son, Inc. has a dedication to client satisfaction and commitment to quality, guaranteeing help to their clients throughout all stages of the development process. Berry’s preconstruction and construction management services include everything from permitting, cost estimating and engineering to construction oversight, commissioning and project close out, being its focus on the healthcare, education and commercial markets.

William A. Berry & Son is also the only North American construction manager company to receive the Liberty Mutual Gold Award for Safety. This permeation is a result of the in-house “ Q Four Safety Program”. However this is a program that generates mountains of paper that need to be managed and to keep on the top of all the documentations Berry needed to slow down the process and it also required a significant amount of resources to maintain it. Also since all the information was on paper it was almost impossible to measure subcontractor performance across projects.

As a solution to these problems and an improvement to the award winning program William A. Berry decided to adopt BIM 360 Field. Using the Safety Inspection Module as an integral component of the Q Four Program, Berry was able *“to document and verify what’s really happening in the field accurately and quickly”* said Chuck Cobb, General Counsel for Berry. In short, BIM 360 Field user-friendly software helps Berry’s field superintendent and safety inspectors track safety where it happens, eliminating therefor the need to transcribe all the information taken in the field into the master document reducing the human error associated to the manual transcription as well as the time and resources spent in this task.

Michael Willet, project director for Berry emphasis:

“The field staff loves Vela because it’s so easy to use. We go to the area, take care of the inspection, make notes right on the Tablet and, if we’re interrupted, as frequently happens, we can pull the information right back up. Later, we can synchronize it with the master document electronically which eliminates the possibility for transcription errors. And it takes us half the time that it used to take.”

Beyond the Field the Safety inspection Module also brings benefits to the executive part of the company, since it provides Berry’s executives with visibility. The software automatically creates an auditable trail of consistent, repeatable process that gives owners visibility into safety performance and helps protect against lawsuits, making possible to Berry manage safety compliance for sub-contractors across it all portfolio. As Peter Campot, CEO at Berry said *"From the outset, the audit trail showed its value to our legal team and now it has become a standard for executives".*

Concluding with the words of Ralph DiNapoli, Berry's Safety director, *"Vela makes it easy to track safety on job sites and that's important because I can't be everywhere at once", "I can run reports to look at deficiencies on job sites and, if there are trends, we have a safety meeting to talk about why this issue is important and understand why it's coming up. If there's a dispute, I now have all the OSHA* (Occupational Safety & Health Administration) *standards right at my fingertips, so I can pull the ruling right up. And after the meeting, I can use Vela to make sure that any issues are taken care of."*

In summary the application of BIM 360 Field at William A. Berry brought improvement to the company by:

- Saving time and resources in the use of the "Q Four Safety Program", allowing a more efficient work;
- Providing more visibility to the work done regarding safety;
- Ensuring an easier way to track safety across all projects;
- Transforming the safety data into future useful data.

4.4. Suffolk Construction: Liberty Hotel, Boston MA

Suffolk Construction, one of the North America most successful privately held construction management firms, with a relentless drive to add value and to exceed expectations, which elevates Suffolk to the "Building Smart" Status.

Figure 4.4 - Liberty Hotel, Boston MA [32]

The Liberty Hotel (Figure 4.4) project consists in the remodelling of a turn-of-the-century jail in down town Boston into a five-star luxury hotel, within a tight time and budgetary guidelines. Given the complexity and time-consuming communication between the field and design team needed to assure that the project meet the design intent and high quality standards associated with the traditional approach, and the limited time, Suffolk had to find a way to streamline its worklist, punchlist and all the other field processes to increase productivity and maintain quality on this high-visibility project.

The solution found by Suffolk in its search for efficiencies was BIM 360 Field, its ability to work in real time, shaving off hours, days and potentially weeks from projects [32]

With the application of BIM 360 Field Suffolk have seen significant results in four main areas:

- Personnel Productivity – By using BIM 360 Field on-site, field personnel can take notes in real time, essentially automating their field notebook. In return, workers save four to eight hours per week in time that they would have spent taking notes on-site and then transcribing later at the office. [32]
- Project Acceleration – With BIM 360 Field, all processes are done in real time, dramatically reducing the lag time in communications from the field to participating parties. On average, companies see a 10 to 20 percept increase in project acceleration, gaining one to two days a month, and potentially finishing the project one month early on a two-year schedule. This equates to considerable time and financial savings. [32]
- Risk Reduction – By capturing data in real time risks and issues become visible to project leads and management sooner so that these issues can be dealt with in a timely manner before negatively affecting the whole project. [32]
- Cost of Quality – By measuring the cost of quality in real time at various stages in the project, owners can ensure that their payments are in line with the quality of work being delivered so they are never in a situation where the hold back is less than the cost to fix the deficiencies in the work. [32]

Besides these four main areas Sullfolk as a general contractor has to share information and collaborate with multiple parties. By allowing multiple parties to collaborate on and automatically synch multiple versions of the same document, and the far superior quality of the electronic output, reports and documents, BIM 360 Field enables Suffolk to be the master of all project information.

4.5. ROBINS & MORTON: FLORIDA HOSPITAL MEMORIAL MEDICAL CENTRE

Founded in 1946, Robins & Morton was named the #1 top General Contractors in the modern Healthcare construction and design survey. With a leader reputation in healthcare construction, hospitals account for roughly 95% of its business. Known for pushing the boundaries of innovation to go beyond its clients expectations, Robins & Morton start a search for something to make the construction process better, increase efficiency, streamline processes, accelerate project delivery and ensure quality work in the Florida Hospital Memorial Medical Centre (Figure 4.5). In the words of Angel Colon, Robins & Morton Project Manager, *"I was looking for a solution to help capture, organize and track field data, that is easy to manage and procedurally efficient"*.

This $171 million dollars project consists in a 12 floors, 245 beds new hospital, a central energy plant and medical office building, making a total of 68.000 m^2. This complex project involved several buildings and structures to be completed in a sequence, posing several challenges for Robins &

Morton, such as managing over 50 subcontractors, tight schedules, strict budget conditions and intensive coordination requirements.

With the traditional approach Robins & Morton field personnel prepared notes and created work-to-complete and punchlist in more conventional way, Colon said *"Sometimes the punchlist process can be a time consuming and complicated task because there are so many subcontractors, areas, late changes and items being worked on and coordinated. It can very quickly become a difficult task to manage all of these things simultaneously, which could adversely impact the project schedule and quality", "in my experience, I've seen field notes get written on pieces of paper and then handed off to someone to type into a spread sheet elsewhere. Eventually, the information gets distributed to the appropriate parties but the resulting downtime created while waiting to receive the information – sometimes several days – is simply not optimal."*

Figure 4.5 - Florida Hospital Memorial Medical Centre, Ormond Beach [25]

Using BIM 360 Field on the job site, Robins & Morton field personnel (superintendents, project managers) were able to focus more attention on the details of the healthcare construction process, reducing the time and resources invested in weighty, paper-based administration, and to better track items and their status and flawlessly collaborate with other team members. With BIM 360 Field users have a better understanding of where things are and what needs to be completed, in the end, it allowed project personnel to adhere to company policies and procedures in a more consistent, streamlined manner.[25] Colon adds *"It's been extremely beneficial having a synchronized system to more accurately control process, information flow and, in essence, project management", "With Vela Systems, you can have more than one person punching the building simultaneously in different areas or trades. (…) This is of great benefit to expediting the process as a team and to achieve our goal of zero architect punch."*

Through the usage of BIM 360 Field Robins & Morton was able to achieve:

- Faster Collection of data, saving hours and days normally spent on transcription and communication of field reports and punchlist.
- Accelerated project delivery, by reducing communication delays between teams and keeping information flowing flawlessly between stakeholders.

- Better organization, tracking and synchronization of data, eliminating the need to retype field information or hire additional staff to manage paperwork volume.
- Improved service levels with automatic reports generation.
- Reduced risk, providing a secure audit trail of the progress of construction. Established documentation consistency across projects and offices.
- More consistent, measureable approach to quality.
- Immediately gather QA/QC information from projects to proactively identify trends and reduce both jobsite and corporate risks.
- Understand quality performance to better manage post-project evaluations.
- Avoid claims by providing a secure audit trail of the progress of quality and construction.
- Increase profitability by reducing costly rework.
- Accelerating project delivery by saving weeks of time normally spent on inefficient communication of field information.

4.6. BALFOUR BEATTY CONSTRUCTION

Four years ago BIM 360 Field, at the time Vela Systems, was invited by Balfour Beatty Construction (BBC), to participate in a multi-project pilot of its field management software. BBC selected several project throughout the U.S. to validate the return of investment (ROI) of the software.

Accordingly to Assistant Project Manager, Nathan Ducote, *"A big advantage of Vela Systems is that it helped us shave time from the overall project schedule", "this led directly to increased savings through a reduction of general conditions and overhead. Our ROI was more than 300%! In addition, Vela Systems helped us cut people hours almost in half".*

Division President, Sean DeMartino adds: *"We saw during our pilot that Vela's field management software gives us new insight into how we run or business across projects",* making easy to understand that the benefits went beyond individual projects. DeMartino continued pointing that, *"Our Company's success is tied to our ability to manage costs schedule, quality, and safety on all of our projects. We have strong systems in place to manage cost and schedule. With Vela Reports software, we get real-time access to the quality and safety aspects of our performance across projects and subcontractors. This improves our efficiency, reduces our risk, and helps us provide a better end product to our clients".*

The great success of the software in the pilot projects led, Balfour Beatty Construction to implement a company-wide adoption of BIM 360 Field software as a Service (in the Cloud) and tablet PCs (iPads) for use in onsite project management, and field BIM.

4.6.1. SOFTWARE AS A SERVICE (SAAS) – WHY THE CLOUD?

BIM 360 Field is offered by Autodesk as Software as a Service, and the servers needed to run the software do so in the cloud. In the words of Balfour Beatty Director of information Systems, Jason Bentley, *"Running Vela Systems in the cloud reduced our costs in servers and scales to meet the needs of our large company. Putting servers in racks and managing them is something we don't need to worry about anymore. Vela Systems handles it as a part of their solution".* DeMartino adds, *"Having a solution that is cloud based makes it very easy for us to get project started because we don't need to do anything on the IT side to get disk space or server hardware for our projects."*

4.6.2. IPADS

BIM 360 Field iPad app is one "all in one" iPad construction application, including a document library, checklists for QA/QC, Safety, Commissioning and issue creation/sign off for tracking any issues while walking the field. *"iPads with Vela Systems is a perfect platform for what we are accomplishing,"* continued DeMartino. *"Both are intuitive and simple to use. The iPads we've used are durable and we've had zero issues with damaged devices. We use OtterBox Defender Series cases and carry straps. This combination is a must because by having iPads sling worn, it doesn't tie up your hands when climbing ladders or entering enclosed spaces".* Coupled with durable field cases, such as OtterBox Defender Series Cases, long battery life and ease-to-use of iPads have made them a natural fit for construction and the rough conditions of the jobsite.

Figure 4.6 - BBC employee doing final inspection with BIM 360 Field iPad app [26]

Further all work done in the field without internet access is easily uploaded to the master documents and the BIM 360 Field Web and immediately share across the project once the user gets to the trailer with internet connection and the iPad synchronization begins, saving in this way days of time.

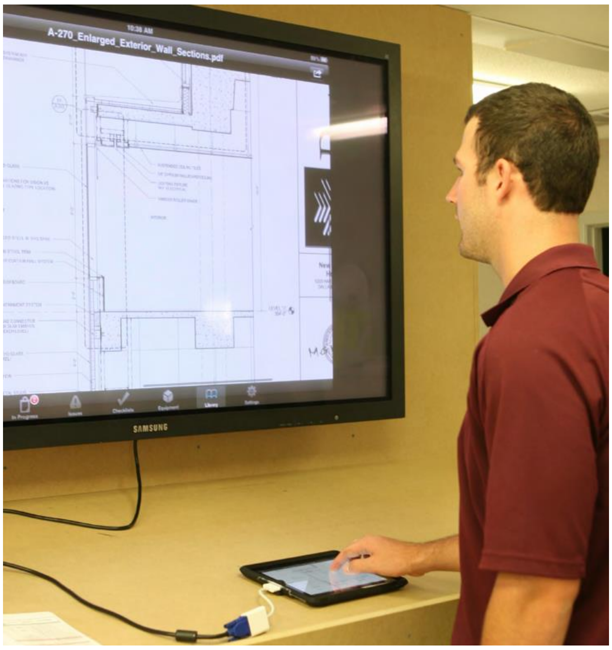

Figure 4.7 - Using BIM 360 Field iPad app to easily review drawings in the trailer [26]

4.6.3. Going Companywide with BIM 360 Field [26]

The number and types of technologies available to construction firms has never been greater, with the iPads, cloud computing, and BIM all creating new value in design and construction delivery. *"with all the options, the challenge is to create a repeatable, flexible platform for easily sharing information across the full project team. We believe that including Vela in our project delivery platform gives us a distinct advantage,"* said Bentley.

The evaluation process for selecting BIM 360 Field involved both operations and information technology teams. *"it is our job in IT to help operations through a rational process for choosing the best technologies that can help our business,"* said Kasey Bevans, Balfour Beatty Construction's CIO. *"We worked with multiple projects, evaluated multiple vendors, and ultimately selected the Vela Systems Field Management Suite due to its ease-of-use, enterprise feature set, product leadership, and overall company services and support."*

As shown in the below graphic, IT and Operations teams identified that the benefits of getting standard operating procedures, access to all modules, and cross-company visibility into quality and safety were key factors in the decision to do a company-wide deployment

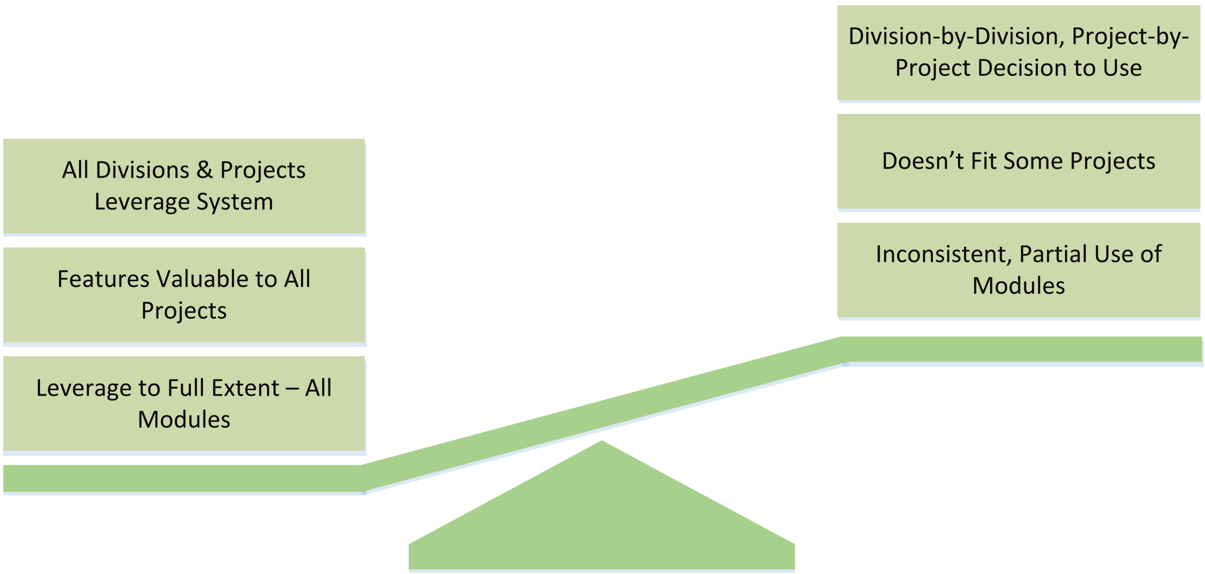

Figure 4.8 - BBC IT and Operations Benefits Balance [26]

4.6.4. Field BIM

Jason Bentley about BIM 360 Field module said *"It complements our BIM investments by extending the value of BIM beyond coordination into the construction and onsite operations of our projects".*

BIM 360 Field exchanges data with the model, back and forward, creating an up-to date Model with new attributes from the field, dynamically updated as work and operations progress. However is important to point out that as BIM 360 Field works as a SaaS, not all information will be stored in the Model, instead it will be stored in the cloud downsizing the size of the Models.

4.6.5. Benefits and Results

Through the multi-project pilot and later with the company-wide implementation of BIM 360 Field, Balfour Beatty Construction field personnel and executives found that the software and its modules have shown its value in different areas as shown below in Figure 4.9.

Issues / Punchlist	QA / QC	Commissioning	Safety
• Reduced time documenting punchlist item • Streamlined processes to meet tighter project completion goals • All team members work from same list and date	• Created strandard library of checklist & QC plans for all projects • Deeper and more consistent compilance monitoring • Early identification of trands which reduces risk	• Reduced handover time for equipment and information • Created "digital asset" to provide to the owner, including drawings, photos and audio recordings • Better management of equipment test & start-up • Sync information with BIM	• Standarized daily Safety Job walks • Streamlined data collection for reporting • Tracked historical Safety performance • Created library of JHAS & AHAs • Improved prevention plans & incident tracking/ reporting

Figure 4.9 - BBC summary of Benefits & Results [26]

4.7. Maryland General Hospital (MGH)

Founded in 1881, Maryland General Hospital (Figure 4.10) in Baltimore was an 245-bed facility serving some 100,000 patients and has more than 500 physicians and 1,400 employees providing an inpatient and outpatient healthcare services. Experiencing substantial growth in admissions, birth, emergency room visits and outpatient visits, MGH started the Central Care Expansion project.

This expansion is a new five-story building attached to the existing hospital including 1,500m^2 of renovated space and 7,000 m^2 of new spaces. With this project MGH will have: eight new operating rooms, a pre-surgical unit with 14 private patient rooms and two inpatient holding bays, a post-anaesthesia care unit with 20 recovery bays and two isolation rooms, a new intensive-care unit of 18 rooms. There is also an updated pharmacy and laboratory and family waiting areas with private consultation rooms.

Figure 4.10 - Maryland General Hospital, Baltimore, Maryland [27]

With all these new facilities comes a vast array of indoor air handling units, chillier plant upgrade which includes two new 650-ton electric centrifugal chillier and 650-ton cooling towers, temperature and humidity systems as well as the necessary duct work, air handlers, dampers and fans, as well as a new 2000 kVA normal power substation, a new 500 kW emergency generator. Which traditionally represent a major commissioning work as Corinne Ambler explains, *"Commissioning typically creates binders and binders of information that are not easily managed and updated. There is data from the mechanical, electrical, product manufacturers, and many others. Typically, we scan hundreds, if not thousands of documents just to create the commissioning books."*

With the help of BIM 360 Field and other BIM software Barton Malow team was able to streamline and improve the commissioning process. Relying on the mechanical contractor's Tekla 3D Model Ambler was able to go further than the electronic cut sheets and owner's manuals. Creating an electronic centralized database that compiled field-generated data gathered during construction with electronic closeout files and associating all documents with the relevant mechanical system component to maximize intelligence and utilization of data into facilities maintenance procedures.

To manage this process Ambler team started by creating a list of mechanical systems in BIM 360 Field, defining bar codes for each unit and then tag the units with the unique bar code designation, linking to each the respective warranty, inspection notes, and relevant documentation.

Then using mobile tablet PC equipped with Bluetooth, wireless connectivity, digital camera, RFID reader and barcode scanner the field team can update key information like installation date and add notes by simply writing on the Tablet PC or selecting options from an on-screen template. Updates are automatically incorporated into BIM 360 Field software and the automatically updated in the Tekla 3D Model. Ambler said, *"We don't need paper plans, journals or clipboards – everything is on the Tablet PC. Then, the information recorded on the Tablet PC is synchronized to the Vela server which is synchronized to the Tekla 3D Model".*

Concluding the commissioning process, at the jobsite trailer Ambler and her team are able to track real time the progress, *"The 3D model becomes a digital dashboard, documenting the every step giving operators a very fast, accurate picture of the exact status of the commissioning process"*, explains Ambler. In the model units that pass contractor inspection turn green followed by the city inspector evaluation and approval turning then red being ready for the handover. Ambler adds *"The same task that used to take us days to manage and track, now take just hours, (...) The model is a powerful way to navigate the structure while facilitating field-specific workflow tasks that are an integral part of commissioning, which includes work-to-complete list, punch list and QA / QC".*

Once the commissioning process was complete, Barton Malow handed the F5 Tablets PCs to MGH facilities management staff for use in on-going operations. [27]

4.8. Barton Malow (Autodesk Navisworks, Revit & BIM 360 Field) [28]

4.8.1. Project Summary

Founded in 1924, Barton Malow delivers a broad range of construction services, including general contracting and construction management. From planning to closeout, Barton Malow can help advance even the largest and most complex projects more efficiently. Two steel production lines currently under construction for the steelmaker Severstal North America Dearborn (Severstal Dearborn) illustrate Barton Malow's proactive approach to project delivery. To help manage the projects, Barton Malow uses Building Information Modelling (BIM) software from Autodesk, including Autodesk Navisworks Manage, Autodesk Revit Structure, Autodesk Revit Architecture, and Autodesk Revit MEP software. Playing a key role from preconstruction to handover to the client, BIM is an integrated process that has helped Barton Malow to:

• Visualize, explore, and understand project characteristics before construction;

• Resolve interferences in advance and prevent additional construction costs;

• Save time by completing some tasks as much as 88 % faster;

• Provide a model-based handover deliverable to the owner that will help minimize start-up time and on-going operational costs.

4.8.2. The Challenge

The Severstal Dearborn construction projects consist of a new pickling line and tandem cold mill in an existing steel manufacturing facility (Figure 4.11). In addition, a new hot dip coating line provides automakers with high-quality automotive steel. When complete, the combined construction cost of the production lines will exceed US$200 million.

Construction on the lines began in 2008, with Barton Malow building only the hot dip coating line. The projects were approximately 20 % complete when, facing economic challenges common to the steel industry, the client put them on hold. When construction was restarted in 2010, Severstal Dearborn chose Barton Malow to manage all construction for both lines and to self-perform all civil work, equipment setting, and boilermaker work.

According to Joe Benvenuto, project manager with Barton Malow, "*Restarting the projects led to many challenges. We saw the BIM process as a means to help identify or eliminate potential problems before they became cost or schedule risk items.*"

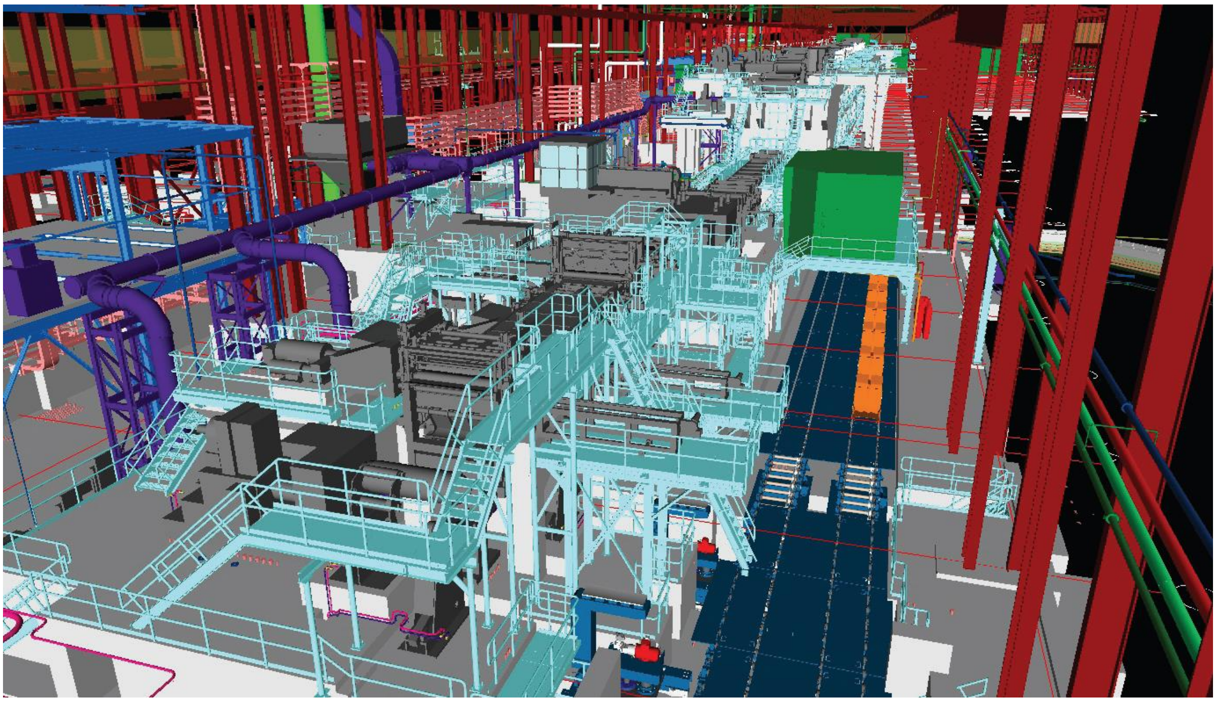

Figure 4.11 - Steel Manufacturing Facility Model Screenshot [28]

4.8.3. The Solution

Before deploying crews to restart construction on the lines, Barton Malow revisited the preconstruction aspects of the projects using a BIM-based process. For the concrete portions, Barton Malow created a detailed structural model in Autodesk Revit Structure software. Within the model, Barton Malow identified the prebuilt portions of the lines and the 35,000 yards of new structural concrete the construction team would install.

"People think of BIM primarily as a design tool," says Benvenuto. *"But BIM gives us the power to explore how we want to build in advance, as well as streamlining our field processes. On the Severstal Dearborn project, Autodesk Revit Structure helped us set up layout controls, design-build 5,000 yards of concrete duct bank, and clarify some incredibly complicated foundations. The construction team saved time and reduced the risk of rework."*

4.8.4. Eliminating Clashes

The use of BIM on the projects extended well beyond the concrete work Barton Malow self-performs. The Barton Malow team and their subcontractors modelled the 6,000 drawings that made up the rest of the construction documentation. Each contractor utilized its own software, with not all of the contractors utilizing Autodesk products. Autodesk Navisworks software allowed Barton Malow to aggregate the various model files into a single, integrated project model. Referring to the model as a guide, Barton Malow explored and visualized its construction plans in collaboration with the engineers and subcontractors.

"*With the Navisworks model, everyone can more easily visualize the project as a whole,"* explains Chris Horney, project engineer for Barton Malow. *"That catalyses collaboration across the project team. Navisworks helps us share ideas about how to optimize construction sequencing, and makes it easier to capture those ideas."*

The Autodesk Navisworks model also proved invaluable for helping resolve coordination issues across disciplines. Within Navisworks software, the team performed clash detection tests. A significant number of conflicts were identified. By working with the project engineers, the team resolved clashes.

4.8.5. BIM for Commissioning and Handover

Using Autodesk BIM 360™ Field, a cloud-based service, Barton Malow is leveraging BIM in the field for construction, commissioning, and ultimately, handover. BIM 360 Field allows workers on the job site to update construction information on mobile devices. Automated integration between the BIM 360 Field service and Autodesk Navisworks software helps keep the single project model updated. Critical information is then available in Navisworks as a BIM-based handover deliverable to the owner. This creates value in on-going operations as owners can save time by finding key documents for training staff and important data, such as warranty start dates for equipment.

According to Horney, using BIM in the field should prove especially valuable during equipment commissioning, "Synchronizing the commissioning process with BIM 360 Field and Navisworks can allow us to link accurate install dates, maintenance manuals, and operational information to the project model. We're saving time as we capture critical data on materials, systems, and equipment."

4.8.6. BIM for Operations

Throughout the project, Severstal Dearborn has reviewed the construction model with extended project stakeholders using Autodesk Navisworks Freedom software, a free* visualization tool. It has helped them keep up with progress and provide feedback.

Most importantly, the construction model can continue to deliver advantages to the company long after construction is complete. Bill McNab, project manager with Severstal Dearborn explains, *"The BIM model and Autodesk Navisworks will give us a way to visualize components and equipment in detail as we maintain the production lines. There's no question that BIM has helped us to save money on construction costs, and we expect it will help with training operators and maintenance personnel in our facility in the future."*

4.8.7. The Results

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4.9. Consigli Construction Co., Inc. (Autodesk Navisworks & Revit)

Framingham State University had three main constructions goals in their new project (North Hall - 12,000 m^2 and 410 bed new residence hall - Figure 4.12): open on time, stay on budget, and minimize disruption to campus activities during construction. With a "construction management at risk" (CMR) delivery method, Consigli Construction Inc. was the company Framingham chose.

Consigli relied in BIM solutions, such as, Autodesk Revit Architecture, BIM 360 Field and Navisworks Manage software, to help them meet the stated university goals. Quoting Howard Hobbs, project manager of Consigli *"BIM allows us to plan everything using intelligent models (...) I cannot praise the benefits of working from models enough. BIM allowed us to anticipate, plan and coordinate every aspect of the project in advance"*.

Figure 4.12 - Framingham State University North Hall [29]

4.9.1. The Challenge

Based on the assumption the new hall would open on time, Framingham had already enlarge their admissions, so the schedule was even more important to the overall success of the project than budget both two goals Consigli committed to fulfil through the CMR delivery method.

"The stakes were high on this project," says Hoobs. *"With enrolment booming, the clock was ticking to have the 410 beds in the new building available for the fall 2011 semester. The project required extensive coordination of the MEP and structural systems. We saw the BIM process helping us to advance the project on schedule while preventing the kinds of issues that can slow work in the field."*

Located in near existing facilities on Framingham's Campus, the site presented a construction challenge. Consigli had to make sure the building process would not disturb students, faculty, or nearby residents. Maura Sullivan, virtual construction specialist for Consigli, explains: *"Logistically, the project presented a number of spaces challenges of concern to students, the university, and the community. We believed that BIM could help us to solve the space challenge, and communicating our plans using 3D flyovers (*Figure 4.13*) and walk-through."*

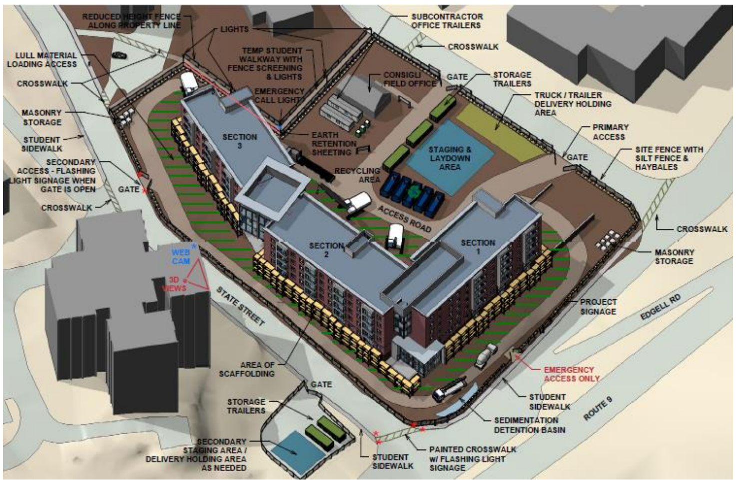

Figure 4.13 - North Hall 3D Flyover [29]

4.9.2. The Solution

Joining to the project at a late stage of the design process, the team began by analysing building models to quickly understand materials and construction technics required to realize the project, as well as opportunities to reduce costs and stream line the construction process without significant alterations to the design, *"As a construction firm, we use models to drive conservations around choices that could enhance the project. Revit Architecture models make it easier for designers and owners to visualize how our insight could make their project more efficient",* said Sullivan.

To reassure all concerned that the construction would not be unduly burdensome, Consigli take the model a step farther. The Firm created a model of the whole building site, including everything from material storage areas to scaffolding and pathways. As Hobbs said, *"People could more easily see they could have safe passage around the construction site for the duration of the project (...) No one wants a big construction site near their home, but neighbours could visualize in 3D the ways we were working to accommodate their concerns. University officials had a better understanding of where we were putting everything, right down to the dumpsters"*.

Besides with the loading of the model into Autodesk Navisworks, Consigli was able to synchronize the construction sequencing with the construction schedule resulting in a 4D schedule that linked activities to the project model.

4.9.3. BIM IN THE FIELD

The advantages of BIM did not stop with the start of the project; with BIM 360 Field Consigli bring BIM into the field. With it Consigli was able to streamline the punch list process as well as the commissioning and handover.

These advantages are highlighted by Consigli BIM Manager, Andy Deschenes talking about punchlists: *"The old way of doing punchlists was very inefficient, (...) you carry around a roll of drawings, marked up, and then entered everything into a spreadsheets. Even using a laptop was a pain. Navisworks and Vela Systems completely transform the process. It's much faster and cleaner. You can even take of puchlist items and link them to the task in Vela Systems."* Continuing into the commissioning and handover process he said: *"Commissioning used to mean turning on the equipment and handing over box after box of manuals to the owner, (...) The process is much more effective with Vela Systems and Navisworks. There's less risk of missing an important step. At handover, the owner can get a model with all the associated equipment information. Linking equipment information to the model makes maintenance over the entire lifecycle of the building easier"*.

4.9.4. RESULTS

Consigli completed the North Hall project and handed over the building to the university well before the opening of the 2011 fall semester. Today, students are enjoying their new residence hall at Framingham. *"The North Hall project was a success in every respect,"* says Hobbs. *"It's a great addition to the heart of the campus. The BIM process contributed immense value. We completed the project on schedule and half a percent under budget. BIM helped make that possible by preventing delays and costly issues."* [29]

4.10. DISCUSSION OF RESULTS

The benefits of the adoption and use of BIM 360 Field are vast and can be organized in very different ways. In this work, the benefits taken from the case-studies analysis, will be organized in four main areas influenced by the software. The Communications since benefits in this area reflect in less miss communication errors and therefor, in a more effective and productive work; the Operations being them the core of a company, is in the operations where most of the valuing added task are, they are the source of income of a construction management company; the Administration since improvement in the construction administration reflects directly in the operations and in the company; and the Quality. The benefits in each of the categories can be found in Table 4.2.

Below will be addressed each benefit singularly. Some of these benefits could have been grouped as a single benefit of time savings, but this time savings does not necessarily represent direct time gain in the total project time, they represent a shift from time spent in non-value-added tasks as transcriptions, to value-added tasks as supervision or job planning.

4.10.1. COMMUNICATIONS

- 1.1 Centralized hub for project information

BIM 360 Field fitted with the storage power of the cloud, becomes a central hub where all up-to-date project information (plans /models / specs/ RFI's) can be easily stored and queried by any team member. Eliminating the errors and rework derived from using out-dated information, as well as, the reduction of time spent in organizing the project information.

Table 4.2 - BIM 360 Field List of Benefits

BIM 360 Field Benefits		
Communications	1.1	Centralized hub for project information
	1.2	Daily notification of worklist items/ quality deficiencies by trades
	1.3	Instant status updates on issues
	1.4	Better communication and observation of issues
	1.5	Improved supervision and job planning
Operations	2.1	Improved Field mobility
	2.2	Improved organization of QA / QC checklist/ worklist/ puchlist and issues
	2.3	Risk reduction
	2.4	Better materials and equipment tracking
	2.5	Improved reporting system
	2.6	Streamlined Process
Administration	3.1	More effective management of the project team
	3.2	Elimination of the transcription of notes
	3.3	Improved availability of project information to project members
	3.4	Quality and Safety compliance across projects
	3.5	Cloud information storage
Quality	4.1	Reduction of costly future rework
	4.2	Better Safety and quality commitment
	4.3	Better visibility towards quality

- 1.2 Daily notification of worklist items/ quality deficiencies by trades.

Maintaining all trades and participants informed of their daily tasks and issues associated to them make workers more effective. Once they have daily base notifications of these matters they can organize their work in a more effective and productive way.

- 1.3 Instant status updates on issues & 1.4 Better communication and observation of issue

These two benefits can be perceived as a follow up of themselves. Due to the instant update on issues a better observation and communication of issues is achieved. With the instant status updates on issues information becomes immediately available elimination the normal downtime created while waiting to the information to be transcribed and passed to the appropriate parties.

- 1.5 Improved supervision and job planning

Through the reduction and elimination of many non-value adding task, construction managers can spent more time focusing in these tasks providing a better founded decision making.

4.10.2. Operations

- 2.1 Improved Field mobility

To the operations area this is one of the major benefit and the sole for many of others. Associated to Tablet PCs, BIM 360 Field provides construction workers with access to the project information and let them perform their duties as checklist/ puchlist directly in the field, and where ever needed. Coupled with the ability to connect to the internet, the information taken in the field is automatically updated to the master document once the tablet is synchronized, providing all project members with the most up-to-date information.

- 2.2 Improved organization of QA / QC checklist/ worklist/ puchlist and issues

With a better communication and organization of the information, comes an far quicker and effective way to deal with the QA/QC, checklist, worklist punchlist and issues, what represents an improvement to efficiency in all the project.

- 2.3 Risk reduction

Creating a clear audit trail of information, improving data management capabilities and providing companies with a better information organization, BIM 360 Field is able to reduce the risk associated to the AEC industry derived from errors like human transcriptions, use of out-dated information, unresolved issues, reducing therefor future costly rework. Being able to more effectively manage materials, equipment, and personnel, construction managers can reduce uncertainties, compensate productivity breaks, and produce/update more effectively schedules.

- 2.4 Better materials and equipment tracking

As mentioned previously, with a better organization of the information, more time to spent in job planning and supervising, coupled with the tablet PCs barcode and RFID readers, BIM 360 Field equips construction and project managers with the ability to more effectively track materials delivery schedules, stock and installation, as well as a better equipment management.

- 2.5 Improved reporting system

BIM 360 Field has the capability to organize the information and automatically create reports instead of the information being transferred and analysed in confusing and time consuming spreadsheets. The software also allows e-mailing the reports to all project participants automatically in a daily, monthly base.

- 2.6 Streamlined Processes

With BIM 360 Field, all processes are done in real time, dramatically reducing the lag time in communication from the field to team members. Combined with a better organization and accessibility of the information, this time reduction reflects in a simplification of most of the process like commissioning and handover, safety, QA/QC. On average, companies see a 10 to 20 percent increase in project acceleration [32] with the use of the software.

4.10.3. Administration

- 3.1 More effective management of the project team

By providing construction and project managers with more organised, visible, understandable, and better information, BIM 360 Field, allows them to spend more time managing in a more effectible way the project team. At the same time with BIM 360 field construction and project managers can manage sub-contractor delivering them daily reports of their worklists and unresolved issues.

- 3.2 Elimination of the transcription of notes

By giving the necessary mobility to access and edit information anywhere with the tablet PCs, BIM 360 Field allows field personnel to take notes in real time, eliminating, therefor, the need to take notes in paper for later transcription, saving worker four to eight hours a week [32] With the elimination of this non-value activity comes the elimination of transcription errors and the time lost preforming this activities, giving field personnel more time to focus on add-value tasks.

- 3.3 Improved availability of project information to project members

With BIM 360 Field all team members have an easy access to project information by just logging in their BIM 360 Field account in any internet accessible computer. In this way, all project information is accessible everywhere.

- 3.4 Quality and Safety compliance across projects

With the storage capability, the immediate availability of information, and the better organization of data, project managers no longer have the need to spend huge amounts of time dealing with quality and safety information making them useful and understandable. Instead they receive this information already in a perceptible way which allows them to focus in preparing and anticipating future problems across all projects without the need to go to jobsites so often.

- 3.5 Cloud information storage

With the Cloud companies no longer have the need of disk space or server hardware to store and manage the projects information. Eliminating therefor, costs with the hardware as well as the indirect costs associated to the time and work needed to be done by the IT department in order to store and manage the information.

4.10.4. Quality

- 4.1 Reduction of costly future rework

Through a better organization of the information, better visualization of the work, better communication and collaboration between team members, and with more time to preform value adding activities as job planning and supervision, the construction team can have a great reduction of errors and therefor, can reduce the amount of rework that when address not in the optimum time can be costly and one of the major reasons for budget overrun.

- 4.2 Better Safety and quality commitment

With a better organization of the safety and quality checklists and punchlists, a better way to analyse and process data related to safety and quality, and with an easier way to track both across projects, construction companies have a better commitment to safety and quality in individual projects and in all of its portfolio.

- 4.3 Better visibility towards quality

This is a benefit that can be visualized as a result of the better quality commitment. Never the less, this is an important benefit. With a better visibility towards quality better work can be performed and in this way elevate the company’s market visibility.

4.11. MICHAEL MORAN MASTER THESIS

Michael Moran's study of BIM 360 Field [22], Moran analyses a sample population of 15 Skanska projects where BIM 360 Field has been used, representing somewhere between 15-20% of the total amount of project where the software has been until the time of the study (spring 2012).

In total where surveyed 38 BIM 360 Field Skanska users and 30 non-Skanska users, from this population, 16 were project engineers, 10 Project managers, and 10 superintendents.

In his study, Moran [22] tests 10 hypotheses:

- H1- BIM 360 Field users will save a significant amount of hours performing their weekly tasks.
- H2- BIM 360 Field users will have varying degrees of efficiency gains based on job description.
- H3- More involvement of other non-Skanska project team members with BIM 360 Field will result in higher efficiency gains.
- H4- Projects whose BIM 360 Field administrators have previous BIM 360 Field experience will have higher efficiency gains
- H5- Projects with special BIM 360 Field trainers will have higher efficiency gains
- H6- Earlier project implementation will result in higher efficiency gains
- H7- Using more functionality tools will result in higher efficiency gains
- H8- The project contract structure will affect efficiency gains,
- H9- Procurement type will affect efficiency gains
- H10- Project size will affect efficiency gains

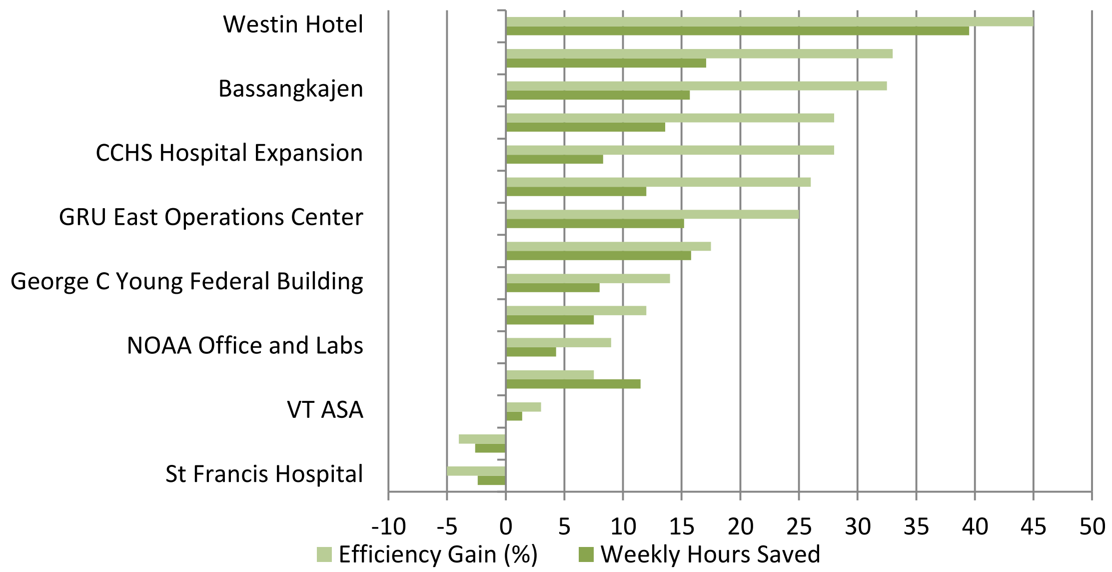

Figure 4.14 - Time savings and efficiency gains on all projects [22]

From these hypotheses only H4 and H6 were rejected by the collected data, while only H3 and H5 were confirmed, all of the others hypotheses were suggested by the data but could not be confirmed.

In order to quantify the results and to be able to compare project performance, Moran [22] uses two primary metrics, the weekly time saved and the efficiency gains across projects and stakeholders (Figure 4.15 and Figure 4.15)

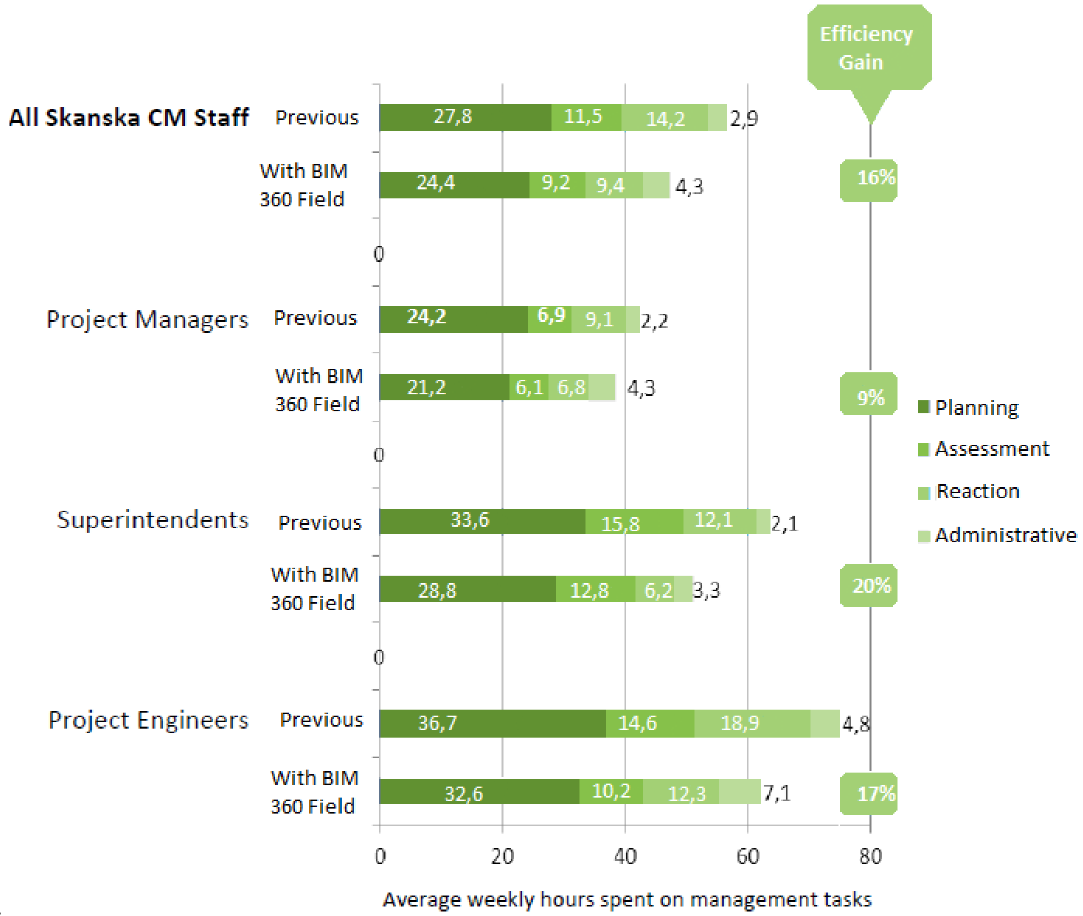

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Figure 4.15 - Breakdown of time spent by project role and task category [22]

The weekly hours saved were calculated by finding the average difference between the total time spent on management task previously to the adoption of BIM 360 Field and after. Efficiency is defined as the time or effort need to achieve a certain result and is expressed as a percentage calculated as follows:

Efficiency gain = (weekly hours saved / weekly time spent before) * 100

It should be noted that in the projects where time savings and efficiency are negative, doesn't mean that they are not getting any benefits, through the creation of accurate issue databases Skanska can achieve lower rework costs and less contingency budget spending.

Through the analyses of the data collected in the 15 projects, Moran [22] concludes that:

- The more involved the non-Skanska parties are, the greater opportunity there is to communicate in a more efficient manner, resulting in efficiency gain.

- The previous exposer to the software doesn't imply efficiency gains. These gains are rather brought by the depth of understanding of the tool.
- The average user saves a significant amount of hours per week performing typical construction management activities using the software.
- The amount of hours saved through the use BIM 360 Field varies depending on job descriptions of construction management staff.
- The project delivery method and contract structure have an influence on average efficiency gain.

It is also important to point out the interesting fact that in all 15 projects only one used an Integrated Project Delivery Method (IPD) and presented an efficiency gain of 45%. This supports the industry wide idea that the collaborative environment of an IPD project enables a fuller, more effective use of BIM's potential applications and benefits, as exemplified in the follow cartoon by Austin Cramer, Managing Editor of *DesignIntelligence*.

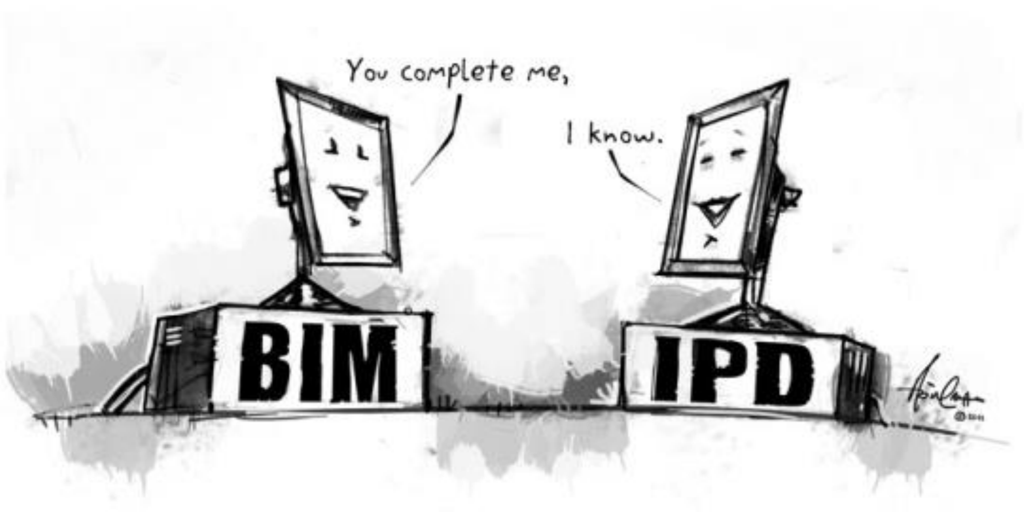

Figure 4.16 - BIM and IPD [33]

5
CONSTRUCTION MANAGEMENT FIRM AND BIM IMPLEMENTATION

5.1. Introduction

To successfully implement BIM, there are some questions that need to be answered. What are the main elements that define the company? What goals want the company achieve with the BIM implementation? As well as, what steps need to be taken to have a successful implementation?

Through the AEC industry there are several differences between construction management companies, there is a vast set of different speciality, volume, and company structure, working at the same time with different delivery methods. This fact makes nearly impossible to formulate an industry wide implementation plan, each case needs to be addressed as a unique case.

However, some general guide lines, should be considered, to successfully implement BIM in a construction management company. Brad Hardin [17] propose a series of ten steps, serving as base for the eight guide lines outlined further in this work, through which companies can start the challenging but rewarding task of implementing BIM. Associated to a BIM implementation, a few points need to be taken in consideration:

- People are the driving force of BIM, and people need to learn;
- BIM is an investment, therefor there will be some time until it paybacks;
- BIM does not do all the work and since it is still developing, there are some impossibilities;
- BIM implementation takes time, small steps should be taken one at a time, in order to see what is working and not;
- Training is as important as any other aspect, if not more;
- The implementation plan should be followed, but it should also be reviewed and adapted to the company relation and adaptation to it;
- Conventions, seminars, and technology expos are the best way to keep track of the market proposals and trends.

5.2. Identify a BIM Manager

The first step towards a BIM implementation is just the same as in any project. When starting a new project, is needed to appoint a project manager, in this case is normally call the BIM manager.

To be able to take the implementation through the best path, the BIM manager needs to have some particular skills, i.e.::

- A technology background, preferably in BIM;
- Good organization and communication skills;
- Praiseworthy managing skills;
- The ability to be trained in new and different software;
- An intimate understanding of the day-to-day functions of the company.

Furthermore, the BIM manager needs to be able to coordinate To coordinate not only the sum of information from all the various areas of expertise (e.g., architects, consulting engineers, and subcontractors) but also project references points and develop a schedule that identifies when tasks need to take place (e.g., clash detection and model updating).

This manager must be familiarized with the BIM software used by the company. However, he doesn't need to be an advanced user of all them but he should understand its purpose and be able to competently explain the software to other users and speak about all the software when reporting the implementation status. Continuous training will keep the company aware of new technologies, methods, resources and trends in the industry through the manager [17].

In short, the BIM manager, as responsible for the lead of this integration process, has to perceive the scopes of the software and its relation with the company's reality. That's the reason why he/she is the key piece on the implementation plan. In order to do that, this manager should prioritize the identification of the steps that are more suitable and add value to the company.

5.3. Develop an Acquisition Plan

The acquisition plan is a management tool through which leadership and the BIM manager are able to idealize and coordinate the purchase of BIM related software and hardware, ensuring its' timely and cost effective acquisition.

Depending on the software/hardware, as well as in the company, the acquisition plan can take different forms and contain an extensive series of information. Despite this fact, there are four main sections, each of them has an unambiguous target containing specific information has described later, that any acquisition plan must have:

- Background and objectives;
- Cost and budget considerations;
- Alternatives, trade-offs, and risks;
- Milestones.

The Background and objectives should include: a statement of need; a software/hardware summary; the applicable conditions, the requirements for compatibility with existing resources and performance constrains; the software/hardware capabilities and performances explaining their relation to the need; and the identification of participants, listing all affected personnel by the acquisition presenting at the same time their relation with the new resources and their area of responsibility.

The Cost and budget considerations should include cost of software, hardware, and additional staff needed to an efficient use of the acquired resource; yearly subscription costs; support costs; training costs; and budget estimates and considerations, explaining the relation between the acquisition and the budget barriers, as well as the possible Return Of Investment (ROI) analysis of the resource.

As the name indicates in the alternatives, trade-offs, and risk section should be included an analyse and a report of the alternatives to the resource proposed to be acquired, comparing the advantages and disadvantages of the alternative; a trade-off analysis intended to understand what a company is gaining and losing when opting for one software; as well as a list of the risks associated to the resource and consequent acquisition. The milestone section has the distinctive role of divide the acquisition in easy to develop and understand stages. Arming the team with the ability to analyse of how the acquisition is working and if necessary make changes to it. The milestones section should include a milestone chart and should define extra milestones for updating the acquisition plan.

The goal of this plan is to give management an idea of the scale of the investment needed, and a clear understanding of the total cost to implement the proposed solution.

Further development of the plan should include a description of each piece of proposed software, a rationale for its use, the cost, and estimates for the time to implement it and train personnel on its use as showed in Figure 5.1.

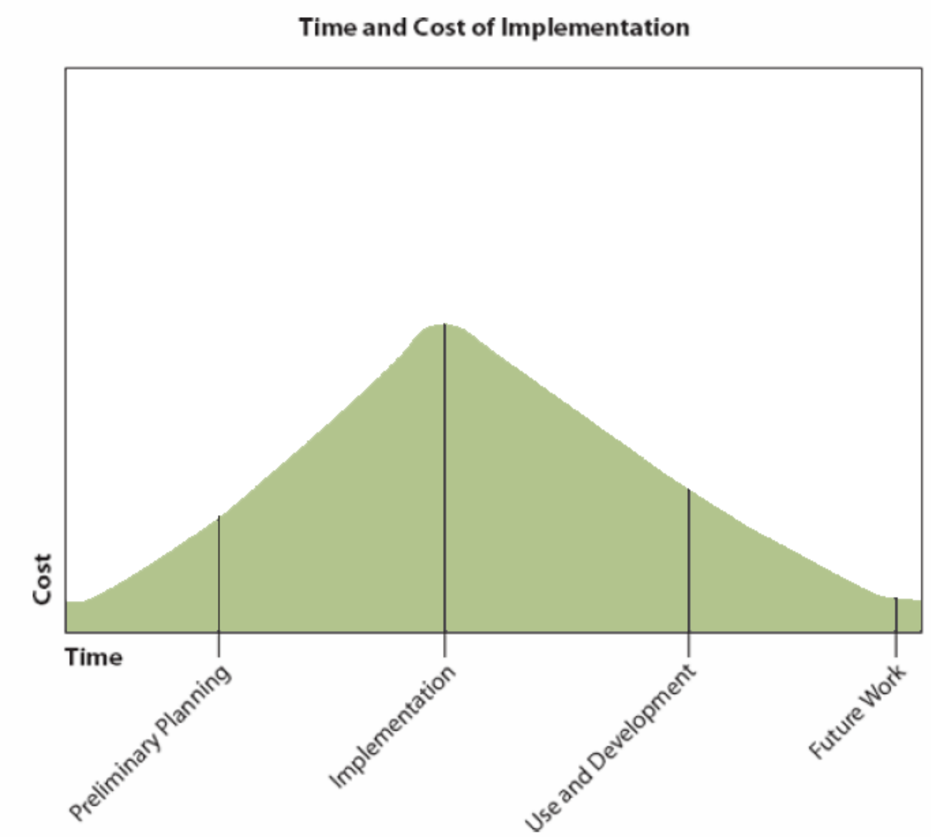

Figure 5.1 - Time vs. Cost of Implementation [17]

In the appendix B an example of an acquisition plan for BIM 360 Field is presented.

5.4. DEVELOP AN INTEGRATION PLAN

As a joint planning exercise, the integration plan, ensures the participation of all stakeholders and affected departments, with the objective of examine all economics, social, and environment cost and benefits, in order to make the best possible decisions and unveil the most appropriate option and course of action to implement BIM.

The BIM integration plan involve not only a software acquisition plan but also a training schedule, a hardware update and maintenance schedule, as well as a specification of the company's BIM evolution. This integration scheme should simultaneously clarify how BIM will interact with the various participants at stake (e.g., stakeholders, departments).

Hardin [17] suggests five components of a integration plan, as Figure 5.2 shows.

Synopsis, this is a brief statement of the company's stance on BIM.

Goals and schedules, this section should include all of the following:

- Goals of the BIM integration
- Purpose of the BIM integration
- Team members' responsibility outlined ; should include new and changed responsibilities
- Software acquisition plan, ch should show the following:
    - Training schedules
    - Hardware update schedules
    - Implementation schedule

Additional operational information, this includes new contracts and new delivery methods.

Future growth plan, this should outline the future goals for BIM at the company.

Supporting articles, this should include journal articles, publications, book excerpts, and statistics that make the case for BIM and identify potential opportunities.

Figure 5.2 - BIM Integration Plan Components [17]

After leadership analyse and approval, the BIM manager can start the implementation, with the challenging task of organize the training and education for associates. While training teaches staff how to do, education teaches people how to think. At the same time, the manager should keep the influence in project and construction management activities, to the minimum possible.

5.5. DEVELOP A BIM DEPARTMENT

While in engineering and architectural companies the BIM implementation often resumes to the adoption of modelling software, in a construction company, it crosses each department embracing multiple pieces of software and overlapping responsibilities.

Expecting the BIM manager to handle all the BIM related subjects in a company is at least unrealistic. The implementation of BIM should be addressed just like a new project. While in a project, companies have project managers supported by several departments, with virtual construction (BIM) there is the need to create a new department to support the BIM manager and the implementation through the company, the BIM department.

5.6. START SMALL

In a BIM implementation, just like in most things, doing everything at once is the first step for disaster. BIM implementation should be done in small steps, one thing at its time, allowing new knowledge to mature and wide spread. In the case of training, it should began by the BIM manager, followed by a few associates from the department in charge of BIM, and only then the remaining associates that will be in direct contact with the software. After their training the associates should start using and implementing the software immediately (i.e. projects for the company), otherwise they will forget what they have learned.

Regarding the choice of the project to the first implementation there are pros and cons, whether it is a small or a big project. This choice shouldn't be taken lightly. While in larger projects the fee is able to fund research and software investments, a small project provides a scalable way to begin using and implementing the software effectively. The project selection preferably should be based in the amount of participants using BIM methodologies, in this case the expression "the more the better" appears to be a perfect fit to transmit the idea. The perfect scenario ultimately is an IPD project, where all stakeholders collaborate in a BIM environment.

5.7. CREATE RESOURCES

New concepts remain fresh for a short period only, after a while, these are either forgotten or become part of the company day-to-day life.

To complement the effort and investment made in the acquisition of resources and training staff, a company implementing BIM should cultivate the investment by creating support material like internal tutorials and guide procedures. Beyond that, is imperative the creation of new process and the adaption of old ones to the new methodologies and workflows imposed by BIM.

Hosted in an easy access place, this support material will help creating a reference and learning point for field personnel, construction managers, and other departments. At the same time, the company is able to improve standardization of how tasks are done internally.

The creation of these new support material and all associated tasks, should be competence of the BIM department and not represent an increase of work to the others departments. In order to people be receptive to BIM and integrating it in their work life, each and every BIM subjects should present itself to them in the simplest way possible, without the need to lose a significant amount of time when faced with issues, and support must be efficient and effective.

5.8. ANALYSE IMPLEMENTATION

When implementing BIM things don't always go as planned and produce the expected results. It is crucial to understand that, being BIM an emerging and continuously growing technology in the AEC industry,(specially to the construction segment), there isn't a default right way to implement BIM. There are so many pieces of software and so many organizations operating with different standards in place that BIM solutions must be customized to complement a company's existing operating platform [17].

Due to this customization, and as a business good practice, companies should perform a distinct analysis: a self-evaluation. Thus, this step will not only permits to understand what is and is not working, but also to realize what must be done in a different manner and where's room for improvement..

While preforming the evaluation and reviewing the implementation results, a company should keep in mind that it is common that things don't work exactly as intended at the first time, and that is not a synonym of a failed implementation, BIM implementation is an iterative process. The company should use the information acquired to improve and evolve their implementation effort, consequently achieving the best outcome from it.

Being this a lengthy task, it can take several years to fully implement BIM, is critical to avoid pointing fingers when possible, not every difficulty is fault of someone, its critical to keep in mind that the BIM implementation is a challenging task beset with difficulties, but at the same time e very rewarding one.

To help companies in this evaluation process, in this work is proposed a benchmark evaluation model, similar to the CMM of NBIMS presented in 2.6.2, designed to measure the "maturity" of a building information model. This evaluation model is designed to measure how a company deals with the BIM implementation, creating metrics to objectify some aspects of this process.

This evaluation model identifies six categories scored on a scale from 1 to 5, to evaluate the BIM implementation, being them:

- Goals;
- BIM Department integration;
- Collaboration;
- Software Effectiveness;
- Staff Adaptation;
- Business Process.

The impact of the implementation on the company can be reviewed trough these categories, having each item a different level of impact within a company. Therefore, the evaluation is done through a benchmark as shown in Table 5.1 - Implementation Evaluation Model, giving to each of the categories a weight.

Table 5.1 - Implementation Evaluation Model

Categories	Weight (a)	Grade (b)	Credit (a x b)
Goals	0,15		
BIM Department Integration	0,15		
Collaboration	0,15		
Software Effectiveness	0,15		
Staff Adaptation	0,25		
Business Process	0,15		
		Total =	

As stated previously, people are the driving force of BIM. Thus, if the staff does not use or have major difficulties adapting and working with the new BIM methodologies, the results of the implementation will most certainly not be as good as they could be. For this reason it is given a weight of 25% to the staff adaptation process, while the remaining categories are assigned with 15%.

The six categories summary description and their scale are presented below.

Goals refers to the number of goals of the BIM integration plan achieved and the improvement brought to the company by them. The scales ranges from no goals achieved to all or most goals achieved with a distinct improvement in productivity and efficiency within the company (see Table 5.2).

Table 5.2 - Goals Category Scale

Goals	
1	None of the goals are achieved
2	None of the goals are achieved but improvement starts to show
3	Some goals are achieved with notorious improvement
4	Most or all goals are achieved still with space for improvement
5	Improvement is evident and most or all goals are achieved.

BIM Department Integration refers to the relation between the BIM department and all the other company departments. As the centre of operations of all BIM related subjects, it should be able to communicate, teach, guide and support all departments through the BIM implementation. The scale ranges from the BIM department do not represent a central hub for all BIM operations, to be fully integrated in the company as a central hub of BIM operations (see Table 5.3).

Table 5.3 - BIM Department Integration Category Scale

BIM Department Integration	
1	BIM Department has major communication and relation issues, it is not the central hub for BIM
2	BIM Department is the central hub of some of BIM subjects but with some major issues
3	BIM Department is the central hub for all BIM subjects still with few issues
4	BIM Department is the central hub for all BIM subjects with minor issues
5	BIM Department is the central hub for all BIM subjects, and fully integrated in the company

Collaboration refers to the relation between the construction company and the other stakeholders, as well as the ability to work in a collaborative environment. It is important to point out that is not the intent of this category to evaluate the level of collaboration used by the company in their projects, rather to unveil how well prepared is the company to collaborate. The scale ranges from not being able to work in a collaborative environment to be fully capable to do so (see Table 5.4).

Table 5.4 - Collaboration Category Scale

Collaboration	
1	Company don't have the ability to work in a collaborative environment
2	Company has tools and staff to work in a collaborative environment with major difficulties and barriers
3	Company is able to work in a collaborative environment with few difficulties and setbacks
4	Company has tools and staff to work in a collaborative environment with minor difficulties and barriers
5	Company has all the necessary tools and staff to work effectively and efficiently in a collaborative environment

Software effectiveness refers to the overall performance of the software. It helps to evaluate how well suited and adequate is the software to perform the expected tasks, as well as if the software is able to improve productivity in the tasks it's used for. The scale ranges from the software being not adequate, to being adequate and represents a productivity gain (see Table 5.5).

Table 5.5 - Software Effectiveness Category Scale

Software Effectiveness	
1	Software is not adequate for its initial purpose
2	Software is adequate for its purpose but represents a productivity loss for users
3	Most of software is adequate for its purpose
4	All software meets its purpose
5	Software is adequate and represents a productivity gain for users

Staff Adaptation refers to the relation of the company employees with BIM. This item allows to gauge how well are people putting BIM to use and adapting to the new processes, workflows and methodology.. The scale ranges from people are reluctant to BIM to people fully integrate it in their day-to-day work life (see Table 5.6).

Table 5.6 - Staff Adaptation Category Scale

Staff Adaptation	
1	People are reluctant to BIM
2	People are reluctant to BIM, but make an effort to integrate it in their workflow
3	Most staff already has fully integrated BIM
4	People already have fully integrated BIM but there still a few barriers to overcome
5	People have fully integrated BIM into their day-to-day work

Business Processes refers to how well the company is adapting their way to do business to BIM. This item allows to gauge how effective are the new processes, how well adapted are the old ones and how business processes change reflects in the company productivity and efficiency. The scale ranges from no change at all, to business processes fully adapted presenting the expected or better results.

Table 5.7 - Business Processes Category Scale

Business Processes	
1	No Business Processes change has happen
2	Business Processes are being created, adapted and implemented in the company
3	Business Processes are being created, adapted and implemented in the company and results start to show
4	Business Processes are being created, adapted and implemented in the company producing positive results and productivity gains.
5	Business Processes are fully adapted to BIM methodology and presents the expected or better results

The final result of the evaluation can be calculated following Table 5.1, and classified in 3 levels like Table 5.8 shows.

Table 5.8 - Evaluation final Classification

Low	High	Level
1	2,5	Minimum BIM
2,5	4	Acceptable BIM
4	5	Successful BIM

A company that achieves a level of minimum BIM is a company that is in an early phase of the implementation and consequently there is still much space for improvement. If a company is already in later phase of the implementation, this result should be a call for attention, and the manager and the leadership should understand that something in the implementation plan went wrong and needs to be changed.

A company that achieves a level of acceptable BIM is a company that is in a good path towards a successfully implementation but there is still room for improvement and should focus in what is not going as expected to understand what could be done better and improve.

A company that achieves a level of Successful BIM is a company that finds themselves in the path for a great BIM implementation and should keep the good work in order to achieve even better results.

Regardless the results, the company should keep always in mind that the implementation is an iterative process, therefore the results and conclusions obtained from this evaluation should be carefully analysed, in order to keep improving. In a BIM implementation as well as in other engineering projects, there's always room for improvement and also perfection takes time.

5.9. Monitor New Software Proposals and Industry Trends

Technology today is moving at an exponential pace. Software development, entrepreneurship, and global communications technologies have created an environment in which being cutting edge requires someone to constantly be informed [17]. That someone is the BIM Manager that by staying aware of the market trends, new software, and industry publications is able to make more informed decisions about the future implementations, and to judge the company’s current status in comparison to the market.

Beyond keeping aware of the market, the company should make an effort for the manager attend BIM technology related conferences, presentations, forums, and construction meetings. By attending these the manager is able to learn how others are using each piece of software and adapt the new information to the company’s reality, gather information from these groups, remain aware of new available technologies, and get an idea for emerging market trends to make more informed decisions later.

6 CONCLUSIONS

6.1. FINAL CONSIDERATIONS

While the results of the study indicated that BIM 360 Field is one software that can help to improve efficiency in construction, is important to recognize the limitations of this study. With the rapid pace of technology development, things change, the hardware becomes better and the software becomes more user friendly. Due to the lack of real project data and some relevant information, it was not possible to clearly differentiate between the versions, nor provide an analysis in the return of investment (ROI) of the software. Nevertheless the overall findings clearly demonstrate the value of this type of software/hardware combination highly rewarding and compensatory. It is also important to keep in mind that is not the intention nor is done in this study an analysis of the specific relations between the software and the independent users, the software and different types of contracts and project collaboration level.

This study concludes that all of the benefits presented in 4.10 are concomitants to three main motives, time savings, quality improvements and efficiency gains, enabling a better execution and service delivery, consequently refining the company's image within the market. All of them are result of three main changes, the processes automation, the greater mobility that the software and associated hardware brings to construction, and the greater documentation management achieved through FDMTs like BIM 360 Field.

This master thesis also addresses the issue of BIM implementation, concluding that although this is a time consuming task and hard to generalize topic with many difficulties and barriers along the way, it is a change that in the end will be rewarding. Associated to the expected difficulties and barriers exists the need to be continuously updating and adapting the implementation. Other important conclusion related to this topic is that being BIM a constantly growing and evolving technology, is of utmost importance that companies stay alert, and keep track of the market trends, in order to be able to take the best advantages from BIM. Simultaneously exist the need to share information about the implementation and learn from the good and bad experiences of other companies, adapting the solutions and information learned from other into the company's reality.

6.2. FUTURE DEVELOPMENTS

Considering this work limitations in terms of data needed to perform better analysis, there are some important studies that can proceed this work.

In relation to BIM 360 Field software would be interesting to develop a more quantitative study based on real project data, intending to provide a better understanding of the relation between construction workers and BIM 360 Field in order to better understand the resources (hardware, Information accessibility, training, and education) needed for an efficient use of it. Trying at the same time to understand the level of adoption and connection that each intervenient need to have with the software (no relation, basic user, medium user, advanced user), in order to better prepare the needed training schedule interfering the minimum possible with the construction activities and staff. As a possible future development there is also the need to perform a well based study about the ROI of the software, preferably based in the experiences of different type of companies, different size projects and delivery methods, analysing the correlation between the ROI of the software and this metrics.

Regarding more qualitative studies about the software would be interesting to analyse the potential benefits and barriers of use BIM 360 Field alongside other BIM software (for example Autodesk's BIM 360 Glue). As well as a study in how can BIM 360 Field, allied to FM software, revolutionize, improve and assist Facility Managers in their work either in existing facilities and new projects.

Regarding future developments about BIM implementation in a construction company, it would be interesting study and further develop the recommendations and guide-lines proposed in this work to a specific company developing a case-study about the implementation, in order to fully understand its implications and utility. Also in order to elevate this guide-lines and recommendations to a construction wide guide would be important to study the relations between the implementation and different types of construction companies, different types of projects and different levels of collaboration between stakeholders and what they imply.

Complementary to these work could also be developed a profound study about the development of a BIM department in different types of companies structures, explaining its relation within the company, its relation with the preparation and accompaniment of projects, its relation with non-company's staff and entities, as well as the staffing methodology.

Being BIM an industry in continuous growth and transformation in obvious that the need for future studies is intrinsic to its nature.

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APPENDICES

APPENDIX A

Name: BIM 360 **Version:** Field

Developer: Autodesk **Type:** Operational Management

Minimum System Requirements:

CPU Type:	Intel Processor 1.8 MHz
Memory:	2 GB RAM
Video Adapter:	Intel GMA (integrated)
	64 MB Video RAM (dedicated)
Hard Disk:	Cloud based Software
Connectivity:	Browser not blocking scripts
	http://bim360.autodesk.com is in the firewall's safe list
	Standard TCP/UDP/IP ports 80 and 443 are not blocked

Supported OS:

Microsoft® Windows®8 32/ 64 -bit
Microsoft® Windows®7 32/ 64 -bit
Microsoft® Windows® XP SP2 (or later)
Apple's iOS (IPad)

Tools & Features

Manage documents	Create and manage issues	Mobile™ iPad
Manage plans	Safety Managment / Control	Project-based reporting
Manage specs	Schedule work for team members	Work online or offline
QA/QC (Checklists)	establish central libraries	
Commissioning	Cross-project (analytic) reporting	

Description: "Autodesk® BIM 360™ Field software, formerly Vela Systems, enables construction and infrastructure industry professionals to combine mobile technologies and BIM at the point of construction. Automation of field processes such as quality, safety, and commissioning checklists; distribution of plans and drawings; and mobile model access helps to provide measurable time and cost savings for architecture, engineering, civil infrastructure and construction projects."

Website: www.autodesk.com/
Address: Autodesk Autodesk, Inc. 111 McInnis Parkway San Rafael, California 94903
Sales Phone: 1-800-964-6432


Serra East>Floor 1>Room SE101
Set to appear on report
Recheck - RFI 1234
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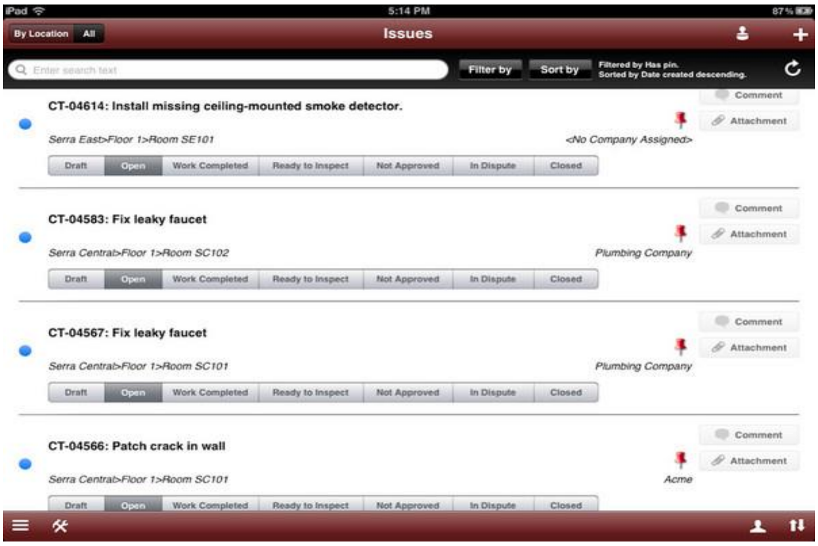
Issue type
Company
Status
Library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By Location
All
Filter by
Sort by
Filtered by Has pin.
Sorted by Date created descending.
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<No Company Assigned>
CT-04583: Fix leaky faucet
Serra Central>Floor 1>Room SC102
Plumbing Company
CT-04567: Fix leaky faucet
Serra Central>Floor 1>Room SC101
Plumbing Company
CT-04566: Patch crack in wall
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In Dispute
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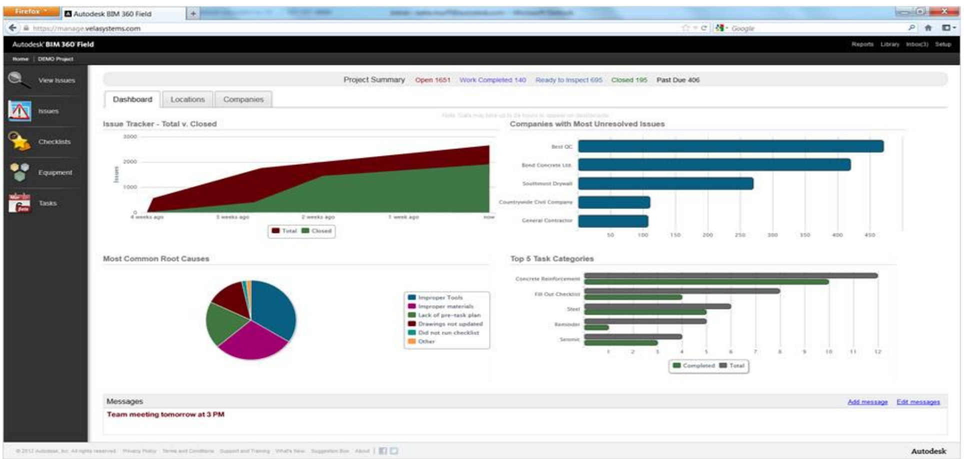

Autodesk BIM 360 Field
Project Summary
Dashboard
Locations
Companies
Issue Tracker - Total v. Closed
Companies with Most Unresolved Issues
Most Common Root Causes
Top 5 Task Categories
Messages
Team meeting tomorrow at 3 PM
Autodesk

Name: Revit **Version:** 2013

Developer: Autodesk **Type:** 3D Modeling
Architecture
Structures
MEP

Minimum System Requirements:

CPU Type:	Single- or Multi-Core Intel® Pentium® i-Series processor or AMD® Xeon®
Memory:	4 GB RAM
Video Display:	1,280 x 1,024 with true color
Video Adapter:	DirectX® 10 with Shader Model 3
Hard Disk:	5 GB free disk space
Pointing Device:	MS-Mouse 3Dconnexion® compliant device
Connectivity:	Internet connection for license registration and prerequisite component download

Supported OS:

Microsoft® Windows®8 32/ 64 -bit
Microsoft® Windows®7 32/ 64 -bit
Microsoft® Windows® XP SP2 (or later)

Readable Files:

*.dgn; *.dwg; *.dxf; *.jpeg; *.png; *.sat; *.skp; *.tif

Writable Files:

*.dwg; *.dxf; *.dgn; *.sat; *.avi; *.jpg; *.tif; *.bmp; *.gif;*.png; *.txt; *.fbx; *.pdf

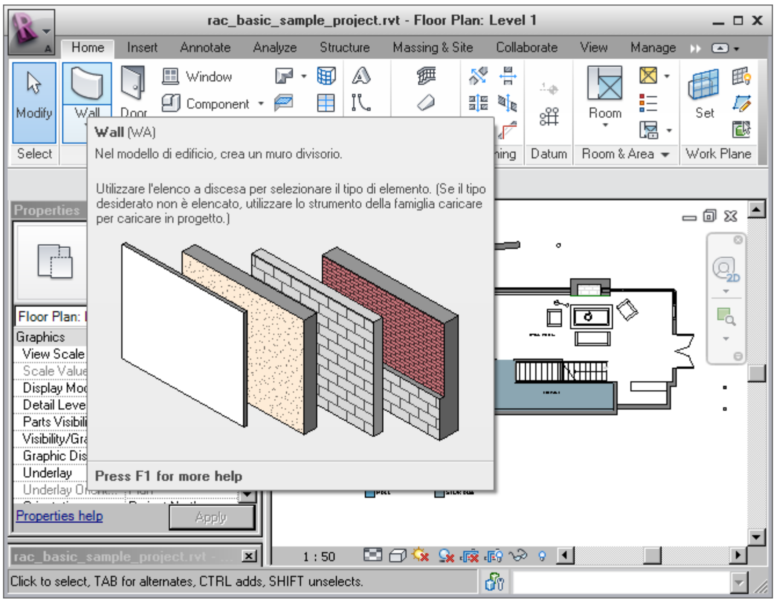
Plug-in: Navisworks NWC (*.NWC)

Tools & Features

2D Drawing	Extrude 3D Models from 2D Designs	Numerical Object Tool
3D Modeling	Generate 2D Drawings from 3D Models	Parametric Modeling
Color Palette	Hatching Editor	Snap-to-Grid Functionality
Command Log	Import Existing Designs	Tape Measure Tool
Customizable Tool Palette	Layer Transparency	Text Box
Drag-and-Drop Modeling	Macro Instruction	Texture Library

Description: "Autodesk Revit software works the way architects and designers think, so you can develop higher-quality, more accurate architectural designs. Using tools specifically built to support Building Information Modeling workflows, you can capture and analyze concepts and maintain your vision through design, documentation, and construction."

Website: www.autodesk.com/
Address: Autodesk Autodesk, Inc. 111 McInnis Parkway San Rafael, California 94903
Sales Phone: 1-800-964-6432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Home
Insert
Annotate
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Collaborate
View
Manage
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Wall
Door
Window
Component
Room
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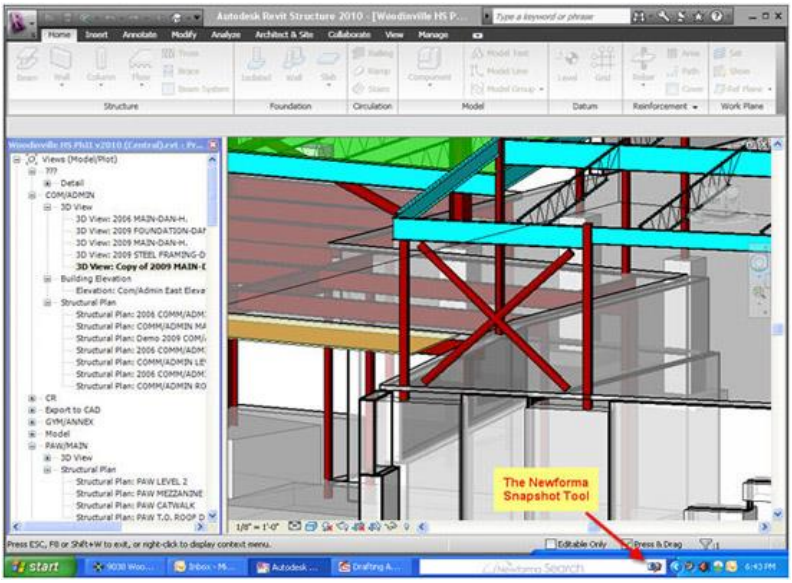
Select
Datum
Room & Area
Work Plane
Wall (WA)
Nel modello di edificio, crea un muro divisorio.
Utilizzare l'elenco a discesa per selezionare il tipo di elemento. (Se il tipo desiderato non è elencato, utilizzare lo strumento della famiglia caricare per caricare in progetto.)
Press F1 for more help
Properties
Floor Plan:
Graphics
View Scale
Properties help
Apply
1 : 50
Click to select, TAB for alternates, CTRL adds, SHIFT unselects.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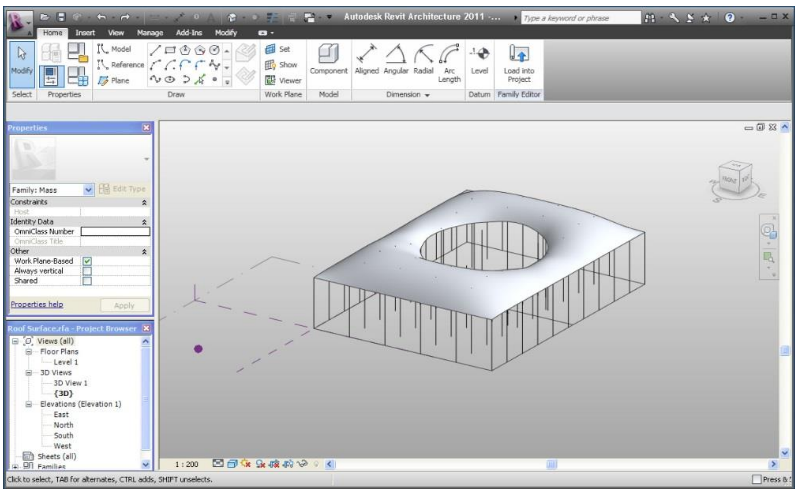
The Newforma Snapshot Tool


Autodesk Revit Architecture 2011
Properties
Properties help
Apply
1 : 200
Click to select, TAB for alternates, CTRL adds, SHIFT unselects.

Name:	Tekla - Structures	**Version:**	17
Developer:	Tekla	**Type:**	3D Modeling Structures

Minimum System Requirements:

CPU Type:	Intel Core 2 Duo CPU 2.40 GHz AMD Athlon 64 X2 5050E AM2
Memory:	4 - 8 GB RAM
Video Display:	21" 1600x1200 24" 1920x1200
Video Adapter:	OpenGL support, 256 - 512 MB
Hard Disk:	150 – 200 GB, 7200 rpm
Pointing Device:	3-button wheel mouse cordless &optical + 3Dconnexion SpacePilot

Supported OS:

Microsoft® Windows®8 32/ 64 -bit
Microsoft® Windows®7 32/ 64 -bit
Microsoft® Windows® XP SP2 (or later)

Imported Files:

CIS/2 format; MIS systems; IFC; DXF; DGN; DWG
external data via links: FEM; SDNF;

Exported Files:

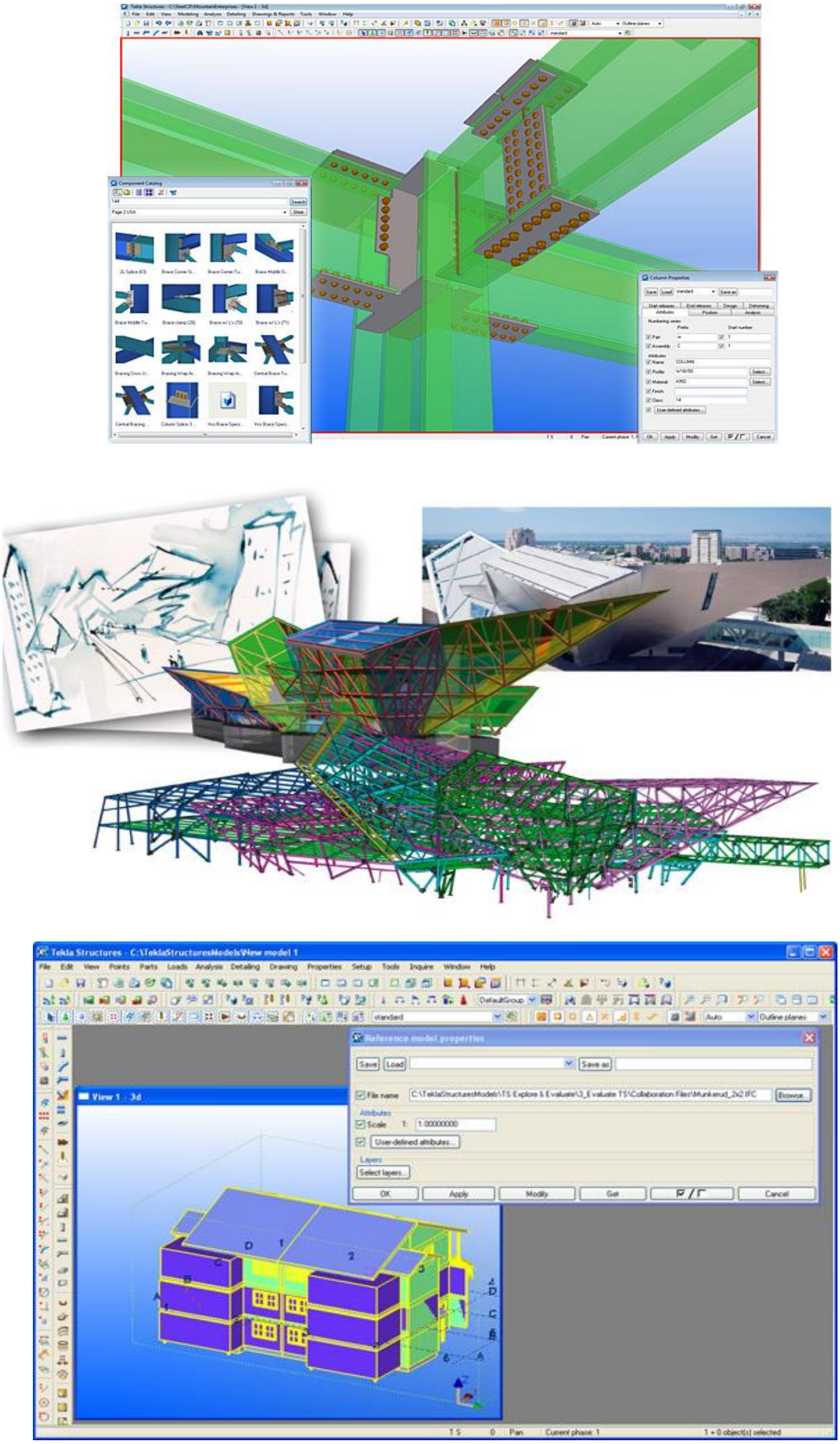
CIS/2 format, MIS systems; CNC; DSTV; IFC; DXF; DGN; DWG

Tools & Features

Create and modify grids	Extrude 3D Models from 2D Designs	Snap-to-Grid Functionality
2D Drawing	Generate 2D Drawings from 3D Models	Tape Measure Tool
3D Modeling	View model information in 4D	Text Box
Numerical Object Tool	Hatching Editor	Texture Library
Parametric Modeling	Import Existing Designs	Macro Instruction
Customizable Tool Palette	Layer Transparency	Color Palette

Description: "Tekla Structures, Full is an all-inclusive configuration containing functionality for all design-to-construction disciplines. Users can create 3D models of both steel and concrete structures, generate output data used during fabrication and erection phases, communicate and manage information from supply to installation as well as track project status."

Website: http://www.tekla.com
Address: Tekla Software Ab, Sigurdsgatan 21, S-721 30 Västerås, Sweden
Sales Phone: +46 21 10 96 00


Tekla Structures - C:\TeklaStructuresModels\New model 1
Reference model properties
View 1 - 3d
File name
Scale
User-defined attributes...
Select layers...
OK
Apply
Modify
Get
Cancel
Current phase: 1

Name: Bim 360 **Version:** Glue

Developer: Autodesk **Type:** Project review

Minimum System Requirements:

CPU Type:	Intel Processor 1.8 MHz
Memory:	2 GB RAM
Video Adapter:	Intel GMA (integrated)
	64 MB Video RAM (dedicated)
Hard Disk:	Cloud based Software
Connectivity:	Browser not blocking scripts
	http://bim360.autodesk.com is in the firewall's safe list
	Standard TCP/UDP/IP ports 80 and 443 are not blocked

Supported OS:

Microsoft® Windows®8 32/ 64 -bit
Microsoft® Windows®7 32/ 64 -bit
Microsoft® Windows® XP SP2 (or later)
Apple's iOS (IPad)

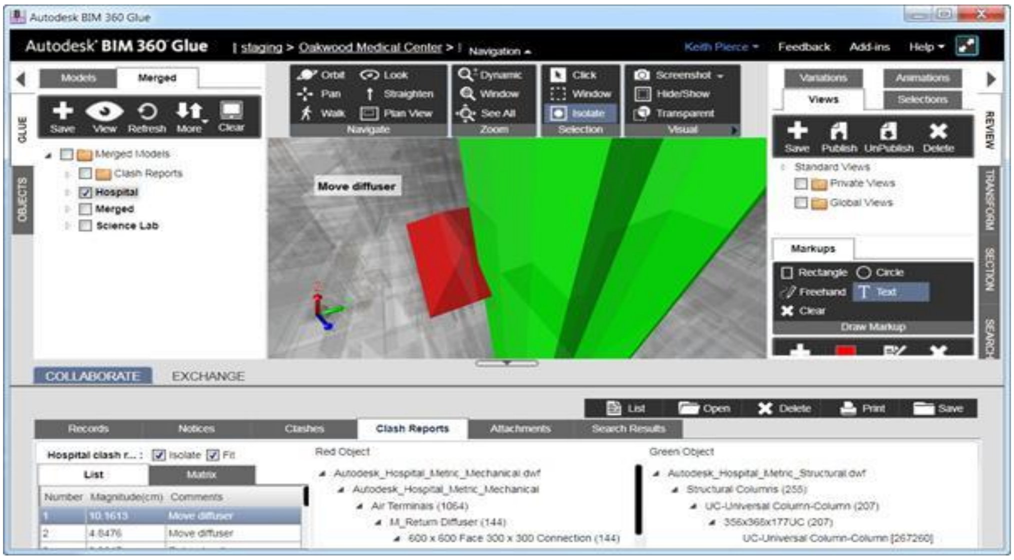
Tools & Features

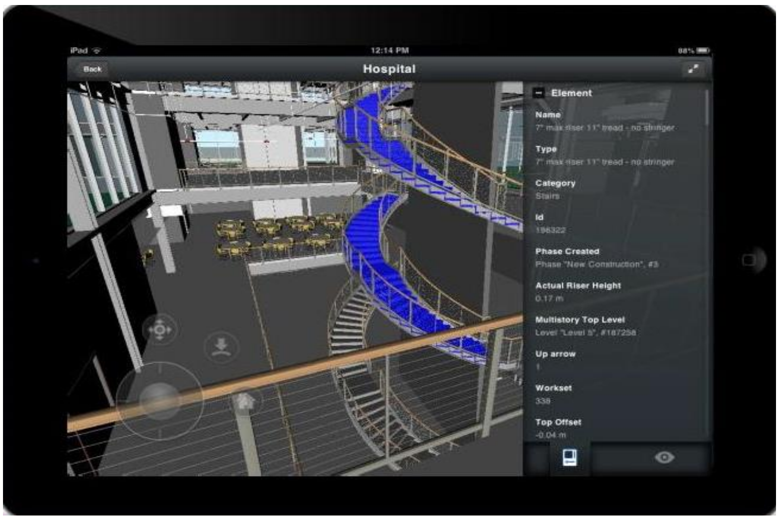
One-Click Access to BIM	Clash Pinpoint Resolution	Review and Markup
Clash Detection	Round-Trip Clash Resolution	
Cloud Based	Immersive Mobile Experience	
Coordination	Point-to-Point Measurement Tools	
Collaboration	Multiple Alternatives in a Single Model	

Description: "Autodesk® BIM 360™ Glue is a data-centric, cloud-based management solution for building and infrastructure projects that provides easier access to project models and data to support collaborative, multidisciplinary workflows across authoring tools and project control applications. It enhances cross-team coordination globally as updates are immediately available in project models. Also available as a mobile app for iPad."

Website: www.autodesk.com/
Address: Autodesk Autodesk, Inc. 111 McInnis Parkway San Rafael, California 94903
Sales Phone: 1-800-964-6432


iPad
12:01 PM
92%
Autodesk®
BIM 360™ Glue
Autodesk Account Sign In
Forgot your password?
Keep me signed in
ON
Sign In
Autodesk®


Autodesk BIM 360 Glue
Autodesk® BIM 360™ Glue
staging > Oakwood Medical Center >
Navigation
Keith Pierce
Feedback
Add-ins
Help
Models
Merged
Save
View
Refresh
More
Clear
Merged Models
Clash Reports
Hospital
Merged
Science Lab
GLUE
OBJECTS
Orbit
Look
Pan
Straighten
Walk
Plan View
Navigate
Dynamic
Window
See All
Zoom
Click
Window
Isolate
Selection
Screenshot
Hide/Show
Transparent
Visual
Move diffuser
Variations
Animations
Views
Selections
Save
Publish
UnPublish
Delete
Standard Views
Private Views
Global Views
Markups
Rectangle
Circle
Freehand
Text
Clear
Draw Markup
REVIEW
TRANSFORM
SECTION
COLLABORATE
EXCHANGE
List
Open
Delete
Print
Save
Records
Notices
Clashes
Clash Reports
Attachments
Search Results
Isolate
Fit
List
Matrix
Number
Magnitude(cm)
Comments
Move diffuser
Move diffuser
Red Object
Autodesk_Hospital_Metric_Mechanical.dwf
Autodesk_Hospital_Metric_Mechanical
Air Terminals (1064)
M_Return Diffuser (144)
600 x 600 Face 300 x 300 Connection (144)
Green Object
Autodesk_Hospital_Metric_Structural.dwf
Structural Columns (255)
UC-Universal Column-Column (207)
356x368x177UC (207)
UC-Universal Column-Column [267260]


12:14 PM
Back
Hospital
Element
Name
Type
Category
Id
Phase Created
Actual Riser Height
Multistory Top Level
Up arrow
Workset
Top Offset

Name:	Vico Office	**Version:**	Suite
Developer:	Vico Systems	**Type:**	Operational Management 4D Simulation

Minimum System Requirements:

CPU Type:	Intel® CPU: Intel Pentium 4 3GHz
Memory:	4 GB RAM
Video Display:	1600x1080
Video Adapter:	High-end OpenGL card
Hard Disk:	10GB of free space

Supported OS:

Microsoft® Windows®8 32/ 64 -bit
Microsoft® Windows®7 32/ 64 -bit
Microsoft® Windows® XP SP2 (or later)

Tools & Features

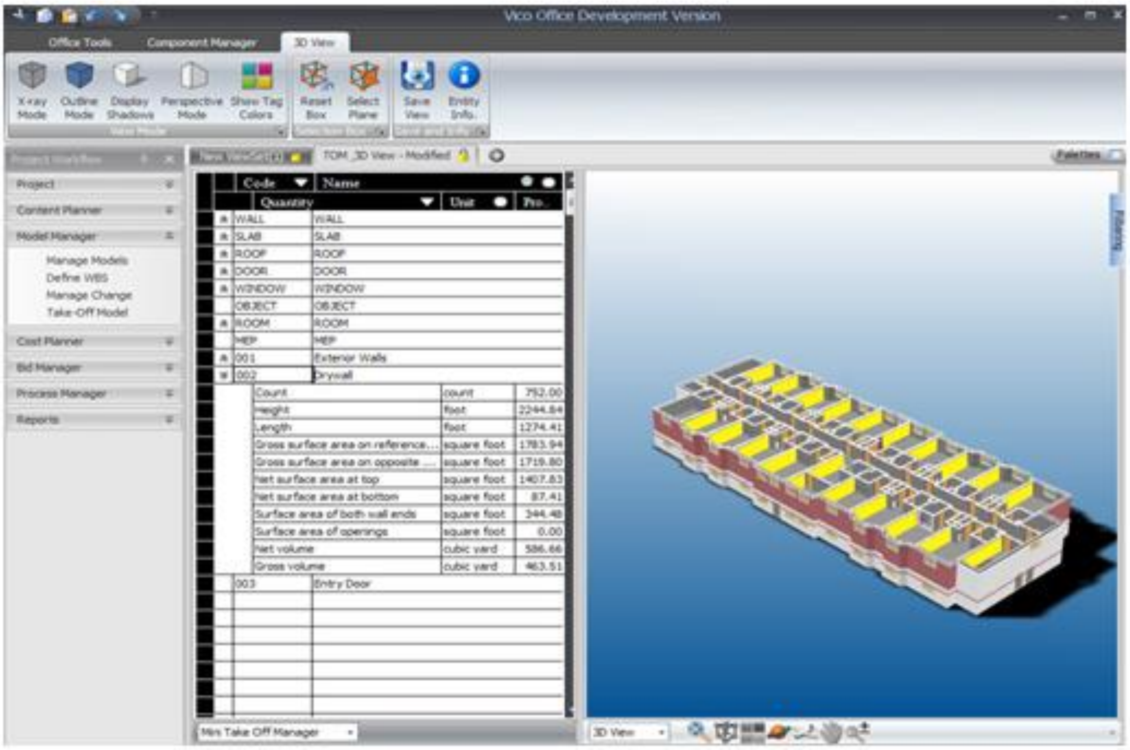
Constructability Issue Report	Mining Production Data: Target, Current	Trimble associacion
Quantity Takeoff Report	Look Ahead Forecast	Flowline View
Quantities by Location	Cash Flow Plans	Resource Histogram
Estimates	Cost- and Resource-Loaded Schedule	Production Control Chart
Cost Plan Variance Report	Visual Budget Report	Clash Detection
On-site production control		

Description: "Vico Office™ is purpose-built for construction, and is designed as a tightly-integrated, BIM-neutral platform to which multiple types of BIM models can be published, synthesized, and augmented with cost and schedule information. To maximize efficiency and meet the distinctive needs of the various construction process trades and phases, Vico Office is structured in a modular way, providing you with a tailored, yet expandable solution and a consistent, easy to use environment."

Website: www.vicosoftware.com
Address: Vico Software, Inc. ; 4730 Walnut Street; Boulder, CO 80301
Sales Phone: (978) 882-0170

Cost Plan Variance Report

		Cost Plan Version 1			Cost Plan Version 2			Variance		
Code	Description	Quantity	Unit	Price	Quantity	Unit	Price	Quantity	Unit	Price
000	QVMC Acute Care Building	0.0		10,392,946.27	0.0		1,979,894.77	0.0		-8,413,051.50
A	SUBSTRUCTURE	25,189.4	-	4,096,859.84	1.0	-	1,131,813.19	-25,188.4	SF	-2,965,046.65
A10	FOUNDATIONS	25,189.4	-	4,096,859.84	0.0	-	1,131,813.19	-25,189.4	SF	-2,965,046.65
A1010	STANDARD FOUNDATIONS	25,189.4	-	1,058,368.15	1.0	-	694,049.76	-25,188.4	SF	-364,318.39
3	Column Encasement	56.0	EA	109,440.96	0.0		0.00	-56.0	EA	-109,440.96
A1012.300.003	Pile Caps	54.0	EA	856,027.29	0.0	EA	694,049.76	-54.0	EA	-161,977.54
03.11.00.107.0	Erect Forms to CIP Concrete - Pile Cap	11,014.3	SF	64,984.21	11,014.3	SF	0.00	0.0	SF	-64,984.21
03.11.00.060	Erect Forms at Pile Cap - Materials	11,014.3	SF	11,014.27	11,014.3	SF	0.00	0.0	SF	-11,014.27
LCON003	Formwork Carpenter	11,014.3	HR	53,969.95	11,014.3	HR	0.00	0.0	HR	-53,969.95
03.11.00.109.0	Strip Forms to CIP Concrete - Pile Cap	11,014.3	SF	9,967.92	11,014.3	SF	0.00	0.0	SF	-9,967.92
03.11.00.061	Strip Froms at Pile Cap - Materials	11,014.3	SF	1,101.43	11,014.3	SF	0.00	0.0	SF	-1,101.43
LCON003	Formwork Carpenter	11,014.3	HR	8,866.49	11,014.3	HR	0.00	0.0	HR	-8,866.49
03.11.00.110.1	Anchor Bolts	54.0	EA	11,512.80	54.0	EA	0.00	0.0	EA	-11,512.80
LCON004.2	Rodman - Anchor Bolt	54.0	HR	11,512.80	54.0	HR	0.00	0.0	HR	-11,512.80
03.11.10.010.0	Layout Pile Caps	54.0	EA	6,480.00	0.0	EA	0.00	-54.0	EA	-6,480.00
03.11.10.010	Layout Pile Caps - Materials	54.0	EA	0.00	0.0	EA	0.00	-54.0	EA	0.00
LCON001	Concrete Labor	54.0	HR	3,240.00	0.0	HR	0.00	-54.0	HR	-3,240.00



Name:	Navisworks	**Version:**	2013
Developer:	Autodesk	**Type:**	Project review

Minimum System Requirements:

CPU Type:	Intel® Pentium® 4 AMD Athlon™ 3.0 GHz with SSE2 technology
Memory:	2 GB RAM
Video Display:	1,280 x 800 VGA display with true color
Video Adapter:	Direct3D 9® and OpenGL®
Hard Disk:	18.5 GB free disk space
Pointing Device:	Microsoft Mouse-compliant pointing device

Supported OS:

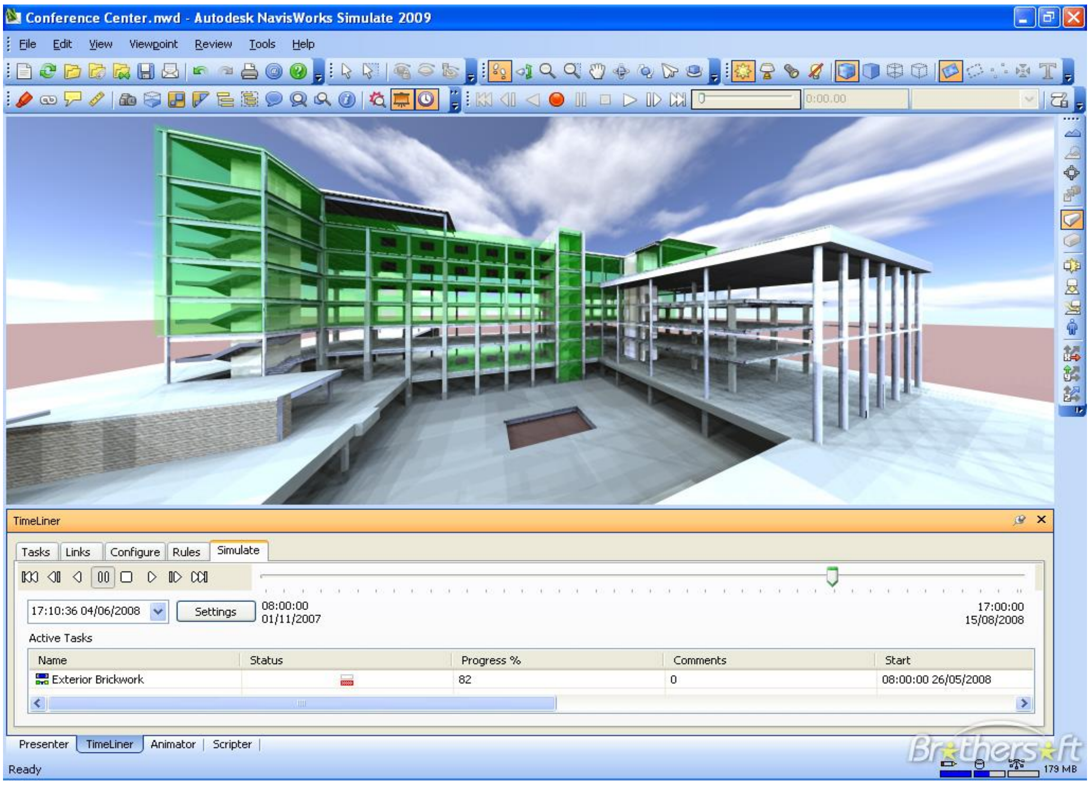
Microsoft® Windows®8 32/ 64 -bit
Microsoft® Windows®7 32/ 64 -bit
Microsoft® Windows® XP SP2 (or later)

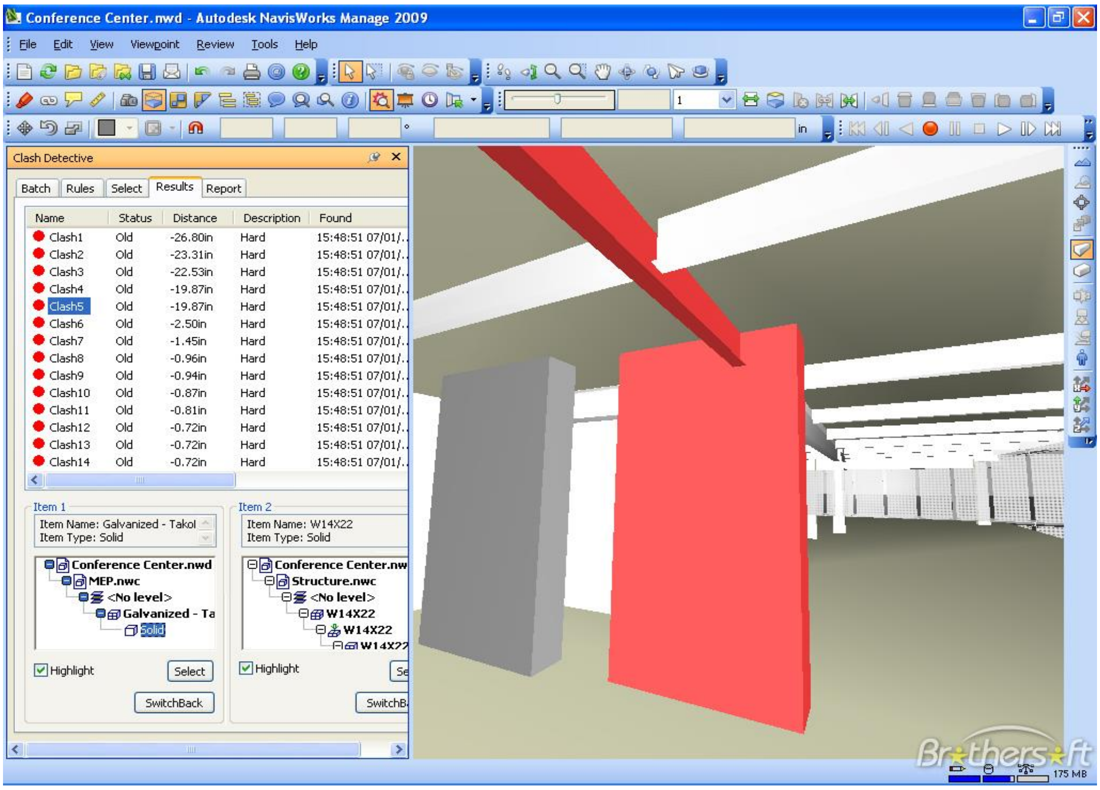
Tools & Features

Clash detection	Clash and interference management	Quantification
interference checking	Model file and data aggregation	Project viewing
Collaboration toolkit	5D project scheduling	Review toolkit
Measurement tools	Photorealistic model	Object animation

Description: "The features of Autodesk® Navisworks® software enable coordination, construction simulation, and project analysis for integrated project review. Navisworks products include advanced tools to simulate and optimize scheduling, identify and coordinate clashes and interferences, collaborate, and gain insight into potential problems."

Website: www.autodesk.com/
Address: Autodesk Autodesk, Inc. 111 McInnis Parkway San Rafael, California 94903
Sales Phone: 1-800-964-6432


Conference Center.nwd - Autodesk NavisWorks Simulate 2009
File Edit View Viewpoint Review Tools Help
TimeLiner
Tasks Links Configure Rules Simulate
17:10:36 04/06/2008
Settings
08:00:00 01/11/2007
17:00:00 15/08/2008
Active Tasks
Name Status Progress % Comments Start
Exterior Brickwork 82 0 08:00:00 26/05/2008
Presenter TimeLiner Animator Scripter
Ready
179 MB


Conference Center.nwd - Autodesk NavisWorks Manage 2009
File Edit View Viewpoint Review Tools Help
Clash Detective
Batch Rules Select Results Report
Name Status Distance Description Found
Clash1 Old -26.80in Hard 15:48:51 07/01/..
Clash2 Old -23.31in Hard 15:48:51 07/01/..
Clash3 Old -22.53in Hard 15:48:51 07/01/..
Clash4 Old -19.87in Hard 15:48:51 07/01/..
Clash5 Old -19.87in Hard 15:48:51 07/01/..
Clash6 Old -2.50in Hard 15:48:51 07/01/..
Clash7 Old -1.45in Hard 15:48:51 07/01/..
Clash8 Old -0.96in Hard 15:48:51 07/01/..
Clash9 Old -0.94in Hard 15:48:51 07/01/..
Clash10 Old -0.87in Hard 15:48:51 07/01/..
Clash11 Old -0.81in Hard 15:48:51 07/01/..
Clash12 Old -0.72in Hard 15:48:51 07/01/..
Clash13 Old -0.72in Hard 15:48:51 07/01/..
Clash14 Old -0.72in Hard 15:48:51 07/01/..
Item 1
Item Name: Galvanized - Takol
Item Type: Solid
Conference Center.nwd
MEP.nwc
<No level>
Galvanized - Ta
Solid
Highlight
Select
SwitchBack
Item 2
Item Name: W14X22
Item Type: Solid
Structure.nwc
W14X22
175 MB

Name: Innovaya **Version:** BIM

Developer: Innovaya **Type:** Operational Management
4D Simulation

Minimum System Requirements:

CPU Type:	Intel® Pentium® 4 1 GHz AMD® Athlon™
Memory:	2 GB RAM
Video Display:	1024 x 768 24-bit colors
Hard Disk:	100 MB free space

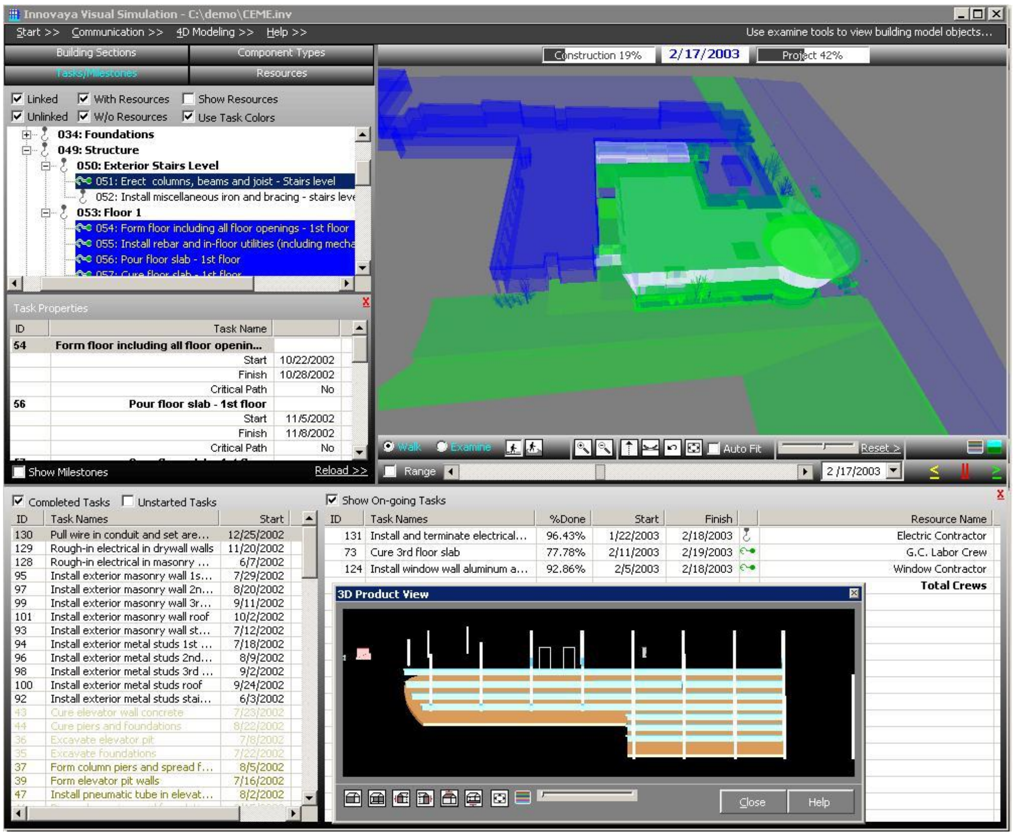
Supported OS:
Microsoft® Windows®8 32/ 64 -bit
Microsoft® Windows®7 32/ 64 -bit
Microsoft® Windows® XP SP2 (or later)

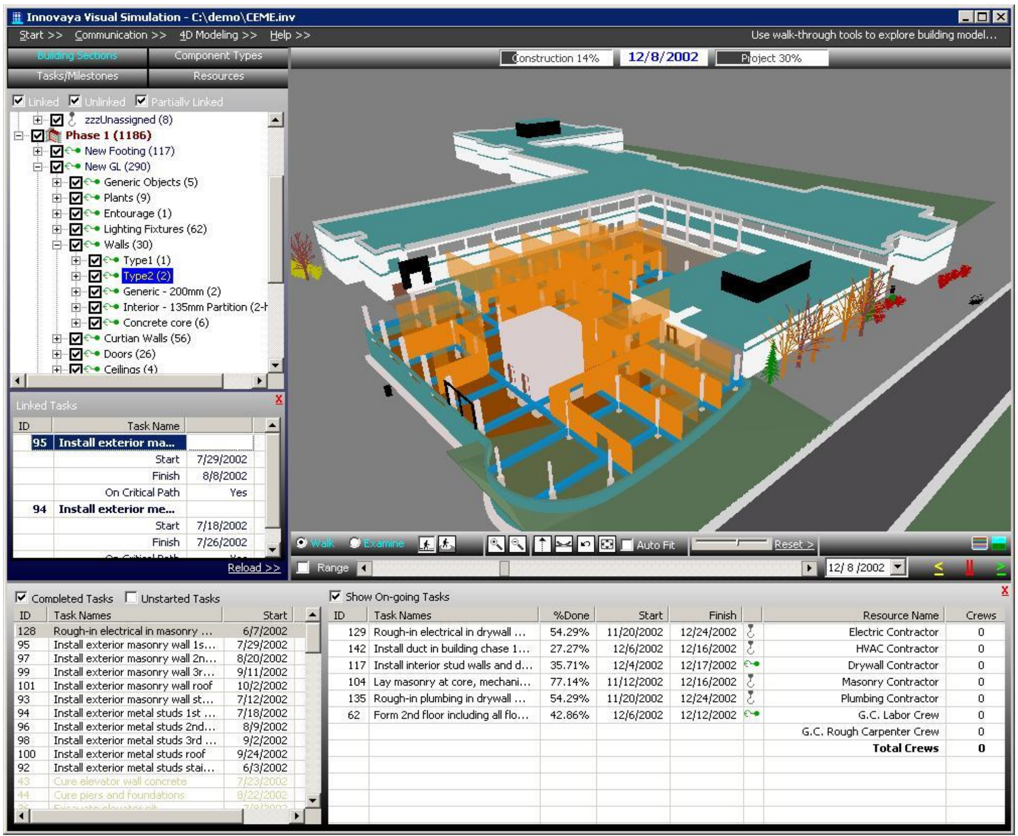
Tools & Features

Interactive 3D Visualization	Dynamic Visibility Controls for 3D Objects	Intelligent Assembly
Automatic Quantity Extraction	Effective Team Communication	Item Takeoff
Estimation to all Model	Automatic Quantity Generation	Assembly Tools
Flexible Estimate Reporting	Drag & Drop Quantity Generation	
Virtual Construction	Intelligent Change Management	
Managed Object Quantities	Optimized Construction Sequencing	

Description: "Designed to take advantage of intelligent building objects in Building Information Models (BIM), this solution revolutionize the way AEC professionals do business, and they effectively improve the communications between designers, builders and clients. As a result, these solutions enormously improve the productivity and efficiency and effectiveness of project coordination, team communication, construction planning, quantity takeoff, and project estimating."

Website: http://www.innovaya.com
Address: 22834 S Eaden Rd, Oregon City, Oregon 97045, USA
Sales Phone: 1-503-488-5836


Innovaya Visual Simulation - C:\demo\CEME.inv
Start >> Communication >> 4D Modeling >> Help >>
Use examine tools to view building model objects...
Building Sections
Component Types
Tasks/Milestones
Resources
Construction 19%
2/17/2003
Project 42%
034: Foundations
049: Structure
050: Exterior Stairs Level
051: Erect columns, beams and joist - Stairs level
052: Install miscellaneous iron and bracing - stairs leve
053: Floor 1
054: Form floor including all floor openings - 1st floor
056: Pour floor slab - 1st floor
Task Properties
Form floor including all floor openin...
Pour floor slab - 1st floor
Show Milestones
Reload >>
Completed Tasks
Unstarted Tasks
Show On-going Tasks
Install and terminate electrical...
Cure 3rd floor slab
Install window wall aluminum a...
Electric Contractor
G.C. Labor Crew
Window Contractor
Total Crews
3D Product View
Close
Help


Innovaya Visual Simulation - C:\demo\CEME.inv
Start >> Communication >> 4D Modeling >> Help >>
Use walk-through tools to explore building model...
Building Sections
Component Types
Tasks/Milestones
Resources
Construction 14%
12/8/2002
Project 30%
Phase 1 (1186)
New Footing (117)
New GL (290)
Walls (30)
Curtian Walls (56)
Doors (26)
Linked Tasks
Install exterior ma...
Install exterior me...
Reload >>
Completed Tasks
Unstarted Tasks
Show On-going Tasks
Electric Contractor
HVAC Contractor
Drywall Contractor
Masonry Contractor
Plumbing Contractor
G.C. Labor Crew
G.C. Rough Carpenter Crew
Total Crews

Name:	Archi	**Version:**	FM	ArchiFM
Developer:	Graphisoft	**Type:**	Facility Management	

Minimum System Requirements:

CPU Type:	Intel® Core or higher 64-bit processor Mac with 64-bit Intel® processor
Memory:	4 GB RAM
Video Display:	1024 x 768 with true color
Video Adapter:	OpenGL and DirectX 9
Hard Disk:	5 GB free disk space

Supported OS:

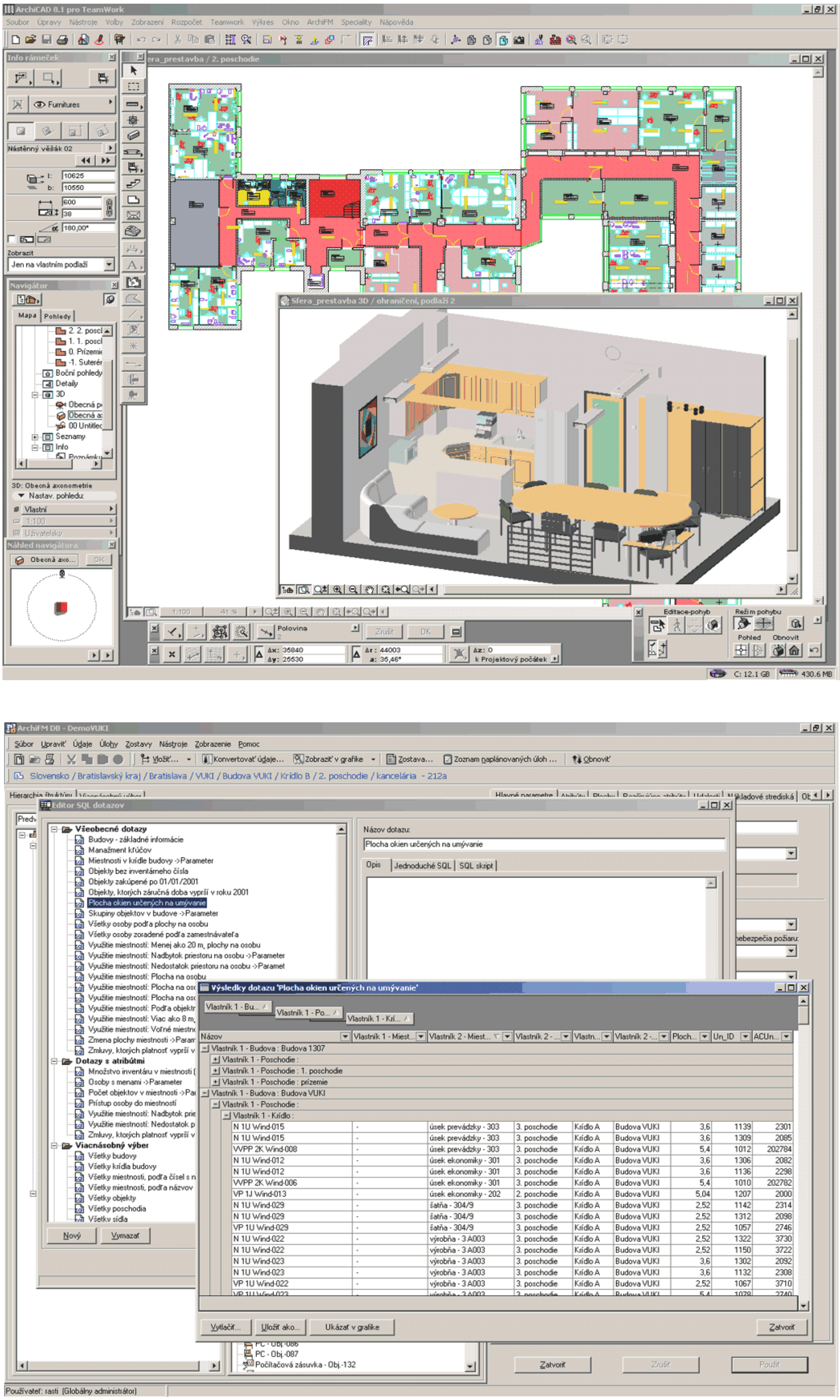
Microsoft® Windows®8 32/ 64 -bit
Microsoft® Windows®7 32/ 64 -bit
Microsoft® Windows® XP SP2 (or later)

Tools & Features

Custom API Development	Dynamic BIM Integration (RealSync™)	Planned maintenance
Area management	Multiple buildings in one database	Breakdown events treatment
Tenant management	Unlimited FM parameters/users	Help Desk/Manuals
Inventory management	Resource planning	Cost management
Maintenance		

Description: "The proven BIM-based solutions of vintoCON, in seamless integration with ArchiCAD, open new dimensions for building professionals throughout the entire building lifecycle - from the design process through the construction stages till the facility operation/maintenance management is established."

Website: http://www.graphisoft.com
Address: Graphisoft One Gateway Center Suite 302 Newton, Massachusetts 2458
Sales Phone: 1-800-238-3992


ArchiCAD 8.1 pro TeamWork
Sfera_prestavba 3D / ohraničení, podlaží 2
ArchiFM DB - DemoVUKI
Slovensko / Bratislavský kraj / Bratislava / VUKI / Budova VUKI / Krídlo B / 2. poschodie / kancelária - 212a
Editor SQL dotazov
Názov dotazu:
Plocha okien určených na umývanie
Výsledky dotazu 'Plocha okien určených na umývanie'
Nový
Vymazať
Vytlačiť...
Uložiť ako...
Ukázať v grafike
Zatvoriť

Name: ArchiCAD **Version:** 16

Developer: Graphisoft **Type:** 3D Modeling
Architecture
MEP (Add-on)

Minimum System Requirements:

CPU Type:	Intel® Core or higher 64-bit processor Mac with 64-bit Intel® processor
Memory:	4 GB RAM
Video Display:	1024 x 768 with true color
Video Adapter:	OpenGL and DirectX 9
Hard Disk:	5 GB free disk space

Supported OS:

Microsoft® Windows®8 32/ 64 -bit
Microsoft® Windows®7 32/ 64 -bit
Microsoft® Windows® XP SP2 (or later)
Mac OSX 10.6 (or later)

Readable Files:

*.bmp; *.dgn; *.dwf; *.dwg; *.dxf;*.emf; *.eps; *.gif; *.hpgl/plt; *.ifc; *.ifcxt; *.jp2; *.jpeg; *.pdf; *.pict; *.png; *.psd; *.qtif; SketchUp; *.tga/targa; *.tif; *.wmf

Writable Files:

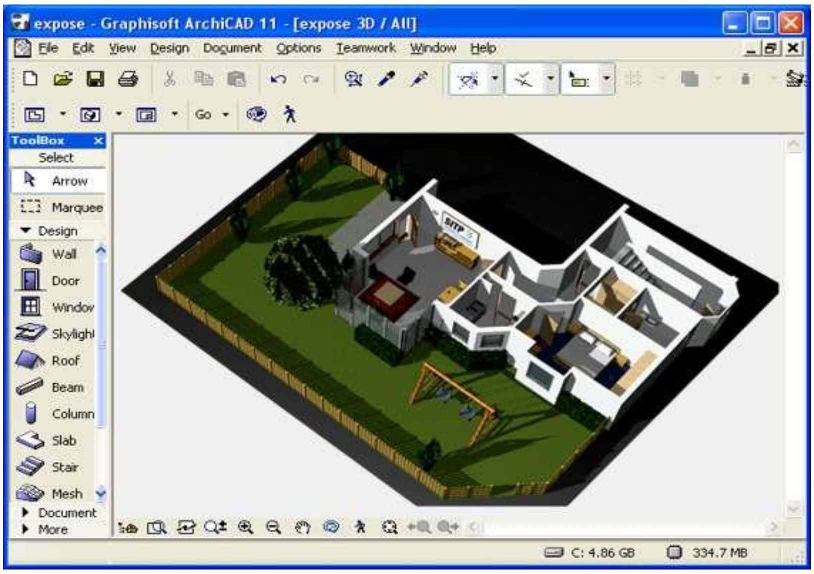
*.avi; *.bmp;*.dgn; *.dwf; *.dwg; *.dxf;*.emf; *.eps; *.gif; *.hpgl/plt; *.ifc; *.ifcxt; *.jp2; *.jpeg; *.obj; *.pdf; *.pict; *.png; *.psd; *.qtif; *.sgi; SketchUp; *.tga/targa; *.tif;

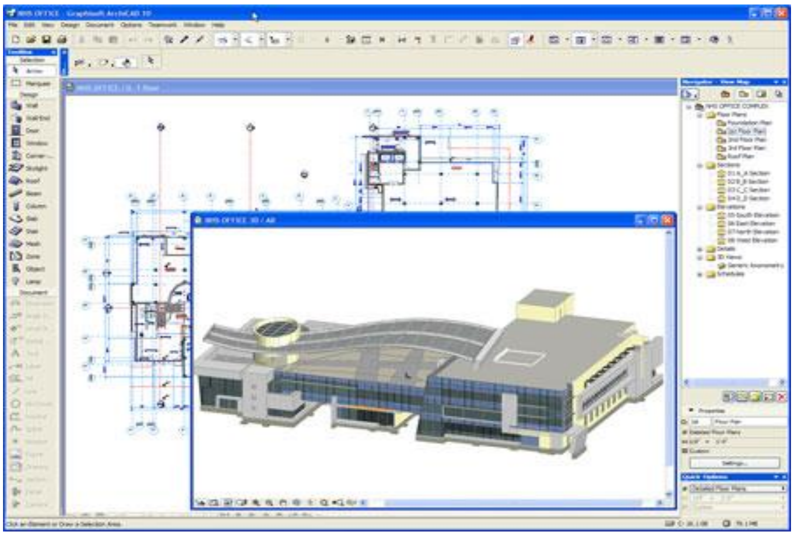
Tools & Features

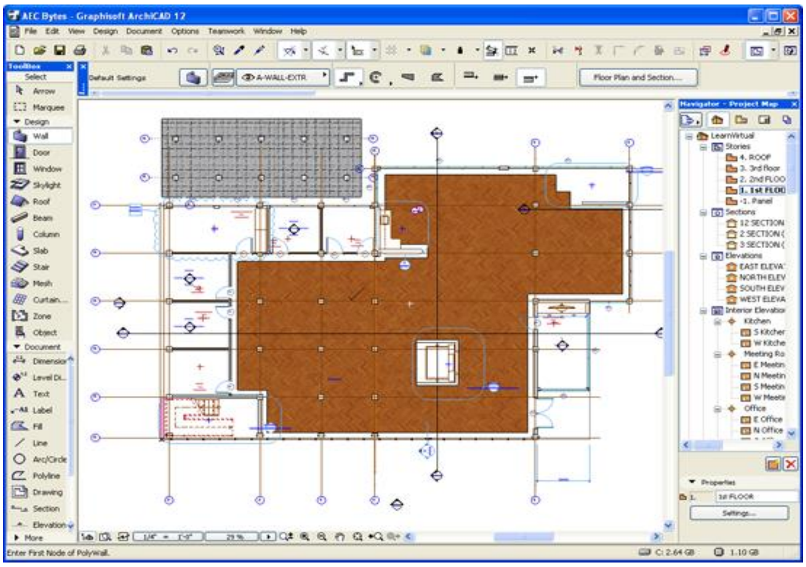
2D Drawing	Extrude 3D Models from 2D Designs	Numerical Object Tool
3D Modeling	Generate 2D Drawings from 3D Models	Parametric Modeling
Color Palette	Hatching Editor	Snap-to-Grid Functionality
Command Log	Import Existing Designs	Tape Measure Tool
Customizable Tool Palette	Layer Transparency	Text Box
Drag-and-Drop Modeling	Macro Instruction	Texture Library

Description: "The evolution of the design process has gone through at least as many revolutionary steps as the forms and structures themselves. ArchiCAD 16 expands the design capabilities of its BIM tools, including new Shell structures, to support the broadest spectrum of architectural shapes and forms prevalent in both classical and modern architecture."

Website: http://www.graphisoft.com
Address: Graphisoft One Gateway Center Suite 302 Newton, Massachusetts 2458
Sales Phone: 1-800-238-3992


expose - Graphisoft ArchiCAD 11 - [expose 3D / All]
File Edit View Design Document Options Teamwork Window Help
ToolBox
Select
Arrow
Marquee
Design
Wall
Door
Window
Skylight
Roof
Beam
Column
Slab
Stair
Mesh
Document
More
C: 4.86 GB
334.7 MB




AEC Bytes - Graphisoft ArchiCAD 12
Navigator - Project Map

Name: MicroStation **Version:** MicroStation V8i

Developer: Bentley **Type:** 3D Modeling
Architecture
Structures
MEP

Minimum System Requirements:

CPU Type:	Intel® or AMD® processor 2.0 GHz
Memory:	2 GB RAM
Video Display:	Color depth set to 24-bit
Video Adapter:	DirectX 9.0c
Hard Disk:	900 MB free disk space

Supported OS:
Microsoft® Windows®8 32/ 64 -bit
Microsoft® Windows®7 32/ 64 -bit
Microsoft® Windows® XP SP2 (or later)
Microsoft® Windows® XP Tablet PC Edition

Readable Files:
*.dgn; *.dwg; *.dxf; *.ifc; *.iges; *.pdf;
*.rvt; Rhino; SketchUp; *.step

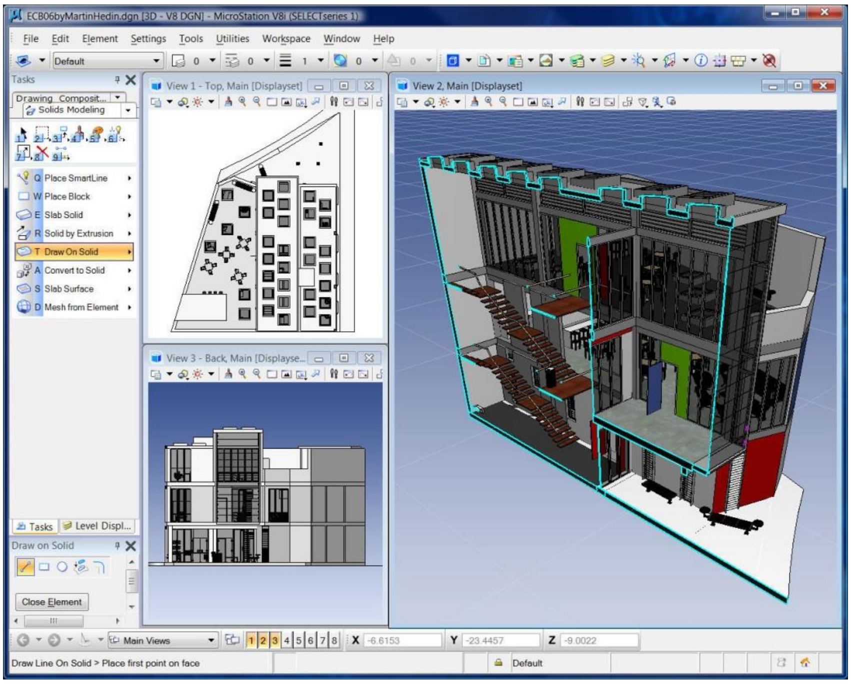
Writable Files:
*:dgn; *.dwg; *.dxf; *.iges; *.pdf;
SketchUp; *.step

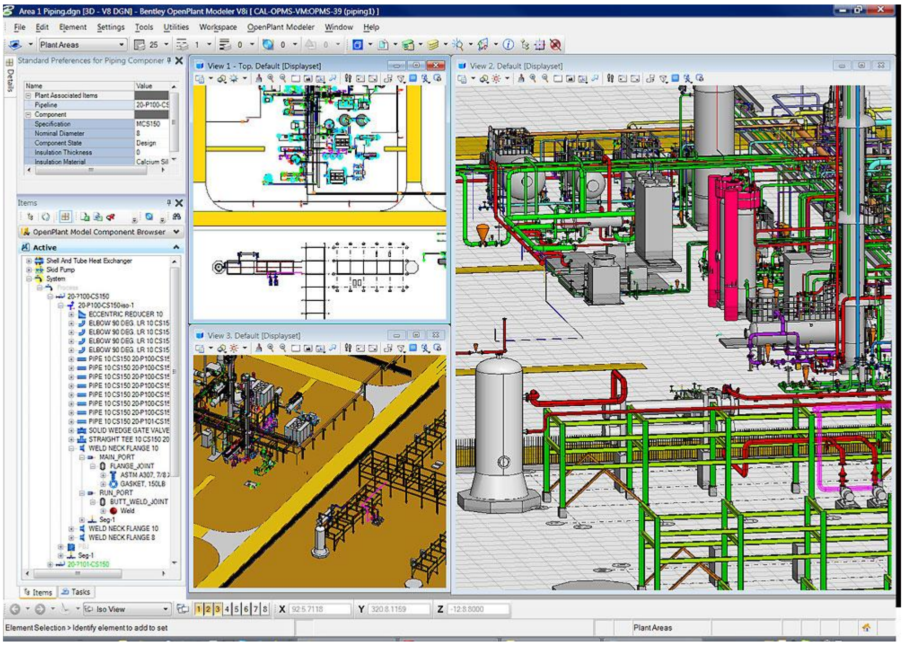
Tools & Features

2D Drawing	Drag-and-Drop Modeling	Layer Transparency
3D Modeling	Extrude 3D Models from 2D Designs	Macro Instruction
Color Palette	Generate 2D Drawings from 3D Models	Numerical Object Tool
Command Log	Hatching Editor	Parametric Modeling
Customizable Tool Palette	Import Existing Designs	Texture Library

Description: "MicroStation is the world's leading information modeling environment explicitly for the architecture, engineering, construction, and operation of all infrastructure types including utility systems, roads and rail, bridges, buildings, communications networks, water and wastewater networks, process plants, mining, and more. MicroStation can be used either as a software application or as a technology platform."

Website: http://www.bentley.com
Address: Bentley Systems 685 Stockton Drive Exton, Pennsylvania 19341
Sales Phone: 1-800-236-8539


File Edit Element Settings Tools Utilities Workspace Window Help
Default
Tasks
Solids Modeling
Place SmartLine
Place Block
Slab Solid
Solid by Extrusion
Draw On Solid
Convert to Solid
Slab Surface
Mesh from Element
View 1 - Top, Main [Displayset]
View 2, Main [Displayset]
Draw on Solid
Close Element
Main Views
Draw Line On Solid > Place first point on face
Default


File Edit Element Settings Tools Utilities Workspace OpenPlant Modeler Window Help
Plant Areas
View 1 - Top, Default [Displayset]
View 2, Default [Displayset]
View 3, Default [Displayset]
OpenPlant Model Component Browser
Active
Iso View
Element Selection > Identify element to add to set
Plant Areas

Name: Facilities **Version:** V8*i*

Developer: Bentley **Type:** Operational Management

Minimum System Requirements:

CPU Type: Intel® CPU: Intel Pentium
Memory: 128MB of RAM
Hard Disk: 35MB free disk space
Pointing Device: Mouse

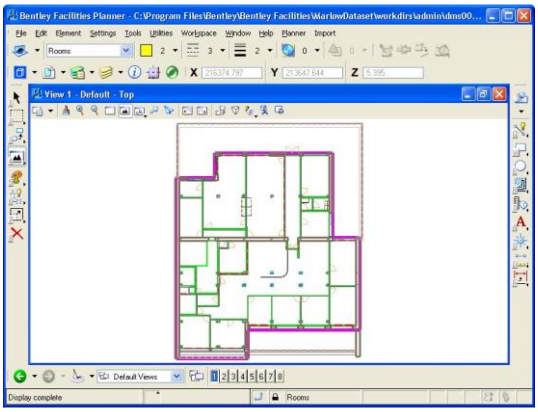
Supported OS:
Microsoft® Windows®8 32/ 64 -bit
Microsoft® Windows®7 32/ 64 -bit
Microsoft® Windows® XP SP2 (or later)

Tools & Features

Space Planner	Space and Asset Management	Equipment Management
Estimate Control	Graphical and Database Information	Quantify the Effects of Changes
Evaluate Ahead	Modify/ Create/ Delete/ Link Information	Browser Based Interface
Plan Ahead	Provides Work Order Functionality	Creates Various Types of Reports
Access all Facility Information	Dynamical Display of Information	Load Balancing

Description: "Bentley Facilities is Bentley's comprehensive Building Information Modeling (BIM) solution for facilities managers. It supports the management of organizational spaces, corporate assets, and facility-related documents, resulting ultimately in better utilized buildings on time and on budget. Facilities management departments of all sizes reap mission-critical and bottom-line benefits as they increase efficiency and effectiveness, avoid costs, and improve their services to the company."

Website: http://www.bentley.com
Address: Bentley Systems 685 Stockton Drive Exton, Pennsylvania 19341
Sales Phone: 1-800-236-8539



APPENDIX B

Software Aquisition Plan

Name: BIM 360 Field **Type:** Operational Management

Developer: Autodesk

Background

Statment of need:

When comparing construction with other industry, it is one of the most inefficient, presenting a reserve growth, when put at the side of others. One of the root causes for this is the fact of 75% of all construction dollars are spent in the field, while, 90 % of the technology is in the trailer and office, the most of management and field activities continue be done in a non-automatic way, there are still a lot of repeated activities, and non-value adding one associated to that "rework" and lack of automation. For that reason there is a need to take technology into the field searching for higher productivity and efficiency.

Software Summary:

Formerly known as Vela Systems, BIM 360 Field was acquired by Autodesk in June of 2012. It is a BIM Field Data Management Tool intended to improve efficiency by automating and reducing the durations of value-adding task and eliminating some of the non-value-adding tasks of the traditional construction processes, such as transcriptions of records.

BIM 360 Field is able to store all project data in a specific log, in the cloud accessible to all stakeholders, automatically compiling the information into useful reports. These reports can be used to analyse delays, RFIs, punchlists items, and rework. At the same time BIM 360 Field organizes all project data and provides a way to classify the information accordingly to its use.

Applicable Conditions:

(explanatory text with the requirements for compatibility with existing company's resources and performance constrains for the software)

Realtion to the need:

Divided in five modules (Material and Equipment Tracking; Quality and Safety checklists; Issues Tracking and Notification; Commissioning and Handover; Documentation Management) and associated to mobile devices as Tablet PCs, BIM 360 Field provides a way to overcome the existing gap between the office and site. BIM 360 Field brings a new way to do and manage construction. With better organized information, displayed in a pratical interface and imediatly available for participants, the capability to input information directly on site, the ability to produce automatic reports, and manage sub-contractor in a more effective way, BIM 360 Field represents possible added-value acquisition.

Requirements:

CPU Type:	Intel Processor 1.8 MHz or higher
Memory:	2 GB RAM
Video Adapter:	Intel GMA (integrated)
	64 MB Video RAM (dedicated)
Hard Disk:	Cloud based Software
Connectivity:	Browser not blocking scripts
	http://bim360.autodesk.com is in the firewall's safe list
	Standard TCP/UDP/IP ports 80 and 443 are not blocked
Extra Hardware:	Mobile devices such as Tablet PCs
Extra Software:	Microsoft office tools or similar
	BIM model compiling software such as Naviswork

Staff Affectance:

The most affected staff by this software is necessarily the personnel associated to site activities, construction management and document management., Accounting for the change inputted to the way work is done there is not only a need for training but also to educate. Autodesk can provide as part of the paid package, on-site and online training, although there is still the need to designate someone to provide additional training.

At the same time there is a need to designated personnel to mass uploading contract documents, establish the location hierarchy which is specific to each individual project, create and upload QA/QC and safety checklists.

Cost and Budget Constrains

Cost:

Equipment	Unit Cost	Units	Time	Total
Software Unlimited users license	$1200	1	24 Months	*$28 800,00*
Live web-based project setup training	$1000	1		*$1000*
Live web-based end-user training	$1500	1		*$1500*
Live web-based Field-BIM trainning	$1500	1		*$1500*
IT cost for initial setup	$2200	1		*$2200*
Microsoft Office Tools or equivelent	$300	1		*$300*
iPad 4 128 GB	$1050	n		*$1050*x*
iPad Protective Case	$90	n		*$90*x*
Bluethoot scanner	$315	n		*$315*x*
Barcode Printer	$415	1		*$415*
Barcode Lables (1,25" x 2,75")	$60	n		*$60*x*
Mobile Eletronic Plan Station	$5500	n		*$11000*
		Total		*$48230*x*

Budget Constrains: *(explanatory text about the relation between the acquisition and the budget barriers)*

ROI Analysis: *(Analysis of the possible Return of investment of the software acquisition)*

Alternatives

Alternative Software:

ArtrA

ArtrA is a building information management system for construction management, fit-out and facilities management.
ArtrA transfers a bim from the design office to the construction team, and then to the FM team.
ArtrA is a Multi-discipline, fully compliant with all BIM/CAD applications, handles IFC and read/writes COBie information.
At its core ArtrA is a (SQL) database management application with a graphical front end (an Active-X version of Navisworks)

Trade-offs: *(report of the company is gains and losses due to the software adoption)*

Risks: Efficiency lost resulting from the change and the need of training.
Reluctance to use the software by other participants (sub-contractors, etc).