BENEFITS AND ROI OF BIM FOR MULTI-DISCIPLINARY PROJECT MANAGEMENT

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BIM is not a panacea for a lack of productivity, lack of experience or lack of knowledge. It is integral for a company to establish an efficient link between the core competencies of its practice and the use of BIM to derive benefits.

Building Information Modeling (BIM) is perceived as the next-generation solution to enhance productivity of stakeholders in the construction industry holistically and streamline the delivery process of buildings and structures. However, there is limited evidence showcasing the existence of frameworks or formulas for project managers to optimize the benefits and ROI of BIM. Researches demonstrating the benefits and ROI of BIM in the Singapore context are unavailable as well.

Project Management is the overall planning, coordination and control of a construction project from inception to completion, involving multi-disciplinary stakeholders from architects to quantity surveyors to contractors. This study focuses on the project- and company-level benefits as well as ROI of BIM implementations – particularly in the Singapore context. It analyzes how experience level and discipline of users will affect the derivation of BIM benefits and change in project management aspects of cost, schedule, quality and safety. Quantitative data was collated through a survey questionnaire designed and sent out to international consultants and contractors operating in Singapore and the results were analyzed using various statistical instruments. Qualitative information describing the in-depth benefits of BIM was also studied through a multi-disciplinary case study. It was subsequently found and statistically proven that benefits derived from BIM are affected by users' experience level and discipline.

To tackle the research problem identified, two models were proposed using the results of the findings. The first model is a self-assessment BIM Optimization Framework while the second is a formula to calculate the cash-flow, ROI and payback period for BIM implementations – to provide both objective and subjective evaluations. Recommendations are also made to local companies operating in the built environment.

Keywords: Building Information Modeling (BIM), Benefits, Return on Investments (ROI), Singapore

Introduction

Project Managers in the construction industry have started to rely significantly on online collaboration and project management (OCPM) technology and computer aided collaborative construction (Becerik & Pollalis, 2006), to shift away from the traditional time- and labour-intensive communication methods, which typically cost higher and are less efficient.

Building Information Modeling (BIM) is perceived as the next-generation solution to enhance productivity of the construction industry holistically. However, while project stakeholders acknowledge the qualitative benefits of utilizing BIM tools, the correlation between the degree of BIM implementation at varying project scales and the benefits to be derived has yet to be studied in detail (Giel & Issa, 2010) and there is a lack of consistency or methodology in measuring the benefits gained (buildingSMART UK, 2010).

Industry observers and regulators argued that the need for BIM in the construction industry is apparent. To this point, however, quantitative information proving the returns on investment (ROI) of BIM has yet to be substantially proven (Becerik-Gerber & Rice, 2009). There is also limited evidence showcasing the existence of theoretical frameworks and process models assisting individuals and/or companies in the construction industry to optimize the benefits, triggered by the implementation of BIM and its allied tools.

This paper sets out to understand the implications and impact of the paradigm shift of implementing and using BIM, with due consideration for the experience level of users and varying construction disciplines in the project management parameters of cost, quality, time and safety. A framework and formula will also be proposed to assist project managers in the field of multi-disciplinary project management to optimize the benefits of BIM implementations both qualitatively and quantitatively.

Research Design

The overall research design in the paper consists of three stages. The first stage, termed as the *inception and development stage,* comprises of the formulation of research objectives as well as an extensive literature review which forms the theoretical framework for the study.

The second stage is known as the *analysis stage*, which commences with the design and administration of the survey questionnaire in accordance to the research objectives, followed by analysis of a multi-disciplinary project management case study, to analyze the benefits of BIM (in-depth) in actual projects. This forms a complete, comprehensive research comprising of both qualitative and quantitative information.

The last stage is the *contribution stage*, where the author utilizes the analyses and results of the previous stages to propose a framework and formula for companies and project managers to better understand the benefits and returns derived from BIM.

Investments for BIM Implementations

The switch from traditional CAD to BIM requires a fundamental transition in terms of staffing, processes as well as significant investments in technology and training (Bratton, 2009). The list of initiative investments for the implementation of BIM are compiled by the author in Table 1. Top-rated areas of BIM investments are reported to be software, developing internal collaborative BIM workflow and procedures, BIM training and new or upgraded hardware.

	Tangible				Intangible	
Investments / Sources	New and/or upgraded hardware (technology)	New and/or upgraded software (technology)	Training and development for staff	New staffing requirements	Cultural changes (new ways of working)	Changes in workflow, processes and/or procedures
(Autodesk, 2011)	√	√	√	√	√	√
(ASHRAE, 2009)	√	√	√	√		√
(Becerik-Gerber & Rice, 2009)	√			√		
(Bedrick, 2005)					√	√
(Bratton, 2009)	√	√	√	√		
(buildingSMART, 2012)	√	√	√	√	√	√
(Eastman, Teicholz, Sacks, & Liston, 2008)	√	√	√	√	√	√
(Gallello, 2008)			√	√	√	
(Hardin, 2009)	√	√	√	√	√	√
(Lamb, Reed, & Khanzode, 2009)	√	√	√	√	√	√
(Light, 2011)	√	√	√			√
(Rocha, 2004)		√	√		√	√
(McGraw Hill Construction, 2009)	√	√	√	√	√	√
(William, 2008)	√	√	√	√		√

Table 1: Investments for BIM identified by various sources. (The list is not exhaustive – author highlighted the most commonly mentioned investments)

Benefits of BIM Implementations

The salient benefits of BIM mentioned by various sources are identified and summarized in Table 2.

Benefits / Sources	Enhanced project collaboration and control among stakeholders	Improved productivity (less re-work, conflicts and changes)	Better project quality and performance	Faster project delivery	Reduced wastages	Reduced construction costs	New revenue and business opportunities
(ASHRAE, 2009)	√	√	√	√	√		√
(Azhar, Hein, & Sketo, 2008)	√		√	√			√
(Becerik-Gerber & Rice, 2009)				√	√	√	
(Beck, 2011)	√			√	√	√	
(buildingSMART, 2010)				√	√	√	√
(El Dado, 2011)	√	√	√	√		√	√
(Giel & Issa, 2010)		√	√	√			
(Han & Damian, 2008)			√	√	√	√	
(Hardin, 2009)	√	√	√	√			√
(Hergunsel, 2011)	√	√		√	√	√	√
(Hurley, 2008)				√	√	√	
(Rodriguez, 2011)	√	√		√	√	√	√
(Underwood & Isikdaq, 2009)	√	√	√	√	√	√	√

Table 2: Key benefits of BIM identified by various sources. The list is not exhaustive – author highlighted only the most commonly mentioned benefits.

In addition, the various benefits of BIM can also be further classified into the various stages of a construction project (Eastman, et al., 2008). The specific benefits and capabilities that BIM confers during different project stages are compiled and categorized in Table 3. It is evident that the most benefits from BIM can be derived during the design and construction stages.

Stage of Construction Project	Benefits to be reaped
Pre-construction Benefits for Owner/Developer	Feasibility study and conceptual design benefits which include enhanced processes and reduction in unnecessary time required
	Schematic model design prior to detailed building model development allows for enhanced evaluation for increased buildability and performance
Benefits during Design Stage	Earlier and more accurate visualizations of Design with 3D model
	Automated corrections (low-level) when design changes are made
	Earlier collaborate and simultaneous work by multiple design disciplines
	Increased accuracy and consistency – of 2D drawings – from early stages and at any stage of the design production phase

	Linking of building model to energy analysis tools (early) to improve energy efficiency and sustainability
	Extraction of bill of quantities for cost estimation
	Design intent checks using 3D visualizations as well as quantification of the space areas
Benefits during Construction Stage	Synchronization of design and construction planning can be done using tools like simulation of construction processes to reveal sources of potential problems
	Clash detection allows for discovery of design errors as well as omissions before actual construction
	Cross system updates enables quicker reaction to design problems or site issues
	BIM model as well as objects and families can be utilized as basis for fabricated components
	Enhance synchronization of procurement with design as well as construction through the generation of 3D models
	Reduction of wastages and better implementation of lean construction techniques
Benefits at the Post-Construction Stage	Model provides a source of information for building systems to for better operations and facilities management
	As-built spaces and systems utilized as a starting point for maintenance and operations, as well as a database for possible future retrofits.

Table 3: Benefits of BIM at various stages of a construction project

Experience Level of Project Manager and BIM Users

The value and associated benefits of BIM are often perceived to be directly proportionate to the experience level of the users (McGraw Hill Construction, 2009). In addition, it was also mentioned by Rodriguez (2011) that cost savings from BIM are more likely to be realized by experienced users and Rosenbloom (2012) as well as Hardin (2009) stressed that it is extremely important to have an experienced BIM Project Manager on the project team in order to gain greater benefits – preferably someone with an appointment that reflects an advanced amount of knowledge and experience.

However, Shennan (2012) warned of that the danger that, because of technology and working practices of BIM that are alien to older generations, those on the BIM front-line may by default be younger staff who are comfortable with the tools but have a shorter track record.

Hypothesis 1: The Benefits and ROI which a company in the local construction industry derives through the implementation of BIM is affected by experience level of BIM users and project managers in the company

Discipline of Users in the Construction Industry

Another intriguing discussion is the determination of the industry stakeholder that stands to benefit most from widespread implementation and deployment of BIM. Succar (2010) suggested that owners and operators stand to benefit most while architects derive the least amount of benefits from BIM.

Rodriguez (2011) concurred that owners ultimately experience all value collectively gained from BIM on a project and contractors are far more likely to experience higher levels of benefits from BIM compared to architects. The 2009 version of the SmartMarket Report presented similar trends, with contractors deriving highest ROI (71%), followed by owners (70%) but only 46% of engineers experienced positive ROI.

Hypothesis 2: The Benefits and ROI which a company in the local construction industry derives through the implementation of BIM varies according to the discipline of the users.

Survey Design and Sampling

A survey was conducted with project managers, building owners, architects, quantity surveyors, M&E engineers, structural engineers and main-contractors who have worked with BIM. The sample selection was carried out using stratified samples by selecting random samples from homogenous strata from the population frame includes consultant and contractor companies retrieved from the Singapore Building and Construction Authority (BCA) Directory of Registered Contractors and Licensed Builders, BCA Register of Accredited Checkers in Accredited Checking Organizations, Public Sector Panel of Consultants and the Singapore Institute of Surveyors and Valuers. The total sample size is 250 and the response rate is 28%.

The aim of the survey was to find out BIM adoption rate and usage pattern, cost implications and impact, project- and company-level benefits derived and the business value of BIM – primarily in the Singapore construction industry.

BIM Adoption and Usage

It is evident from the results obtained that BIM has not gained widespread adoption in Singapore, even with international companies, as most respondents (52%) indicated that BIM is being implemented on less than 20% of projects handled by their company. Only 12% of the respondent companies have employed BIM on 100% of their projects.

The most commonly used BIM software/tool is Autodesk's Revit package of Architecture, Structure and MEP, with 70% of respondents indicating usage, followed by Autodesk Navisworks (40%). 30% chose "Others" which includes CostX, BIMMeasure and CADMeasure, while 20% indicated TEKLA, followed by Bentley (10%), Digital Project (8%), ArchiCAD (6%) as well as Solibri (6%).

The tasks performed by the respondent companies are shown in Figure 1 and the tasks performed by the respondents themselves are presented in Figure 2.

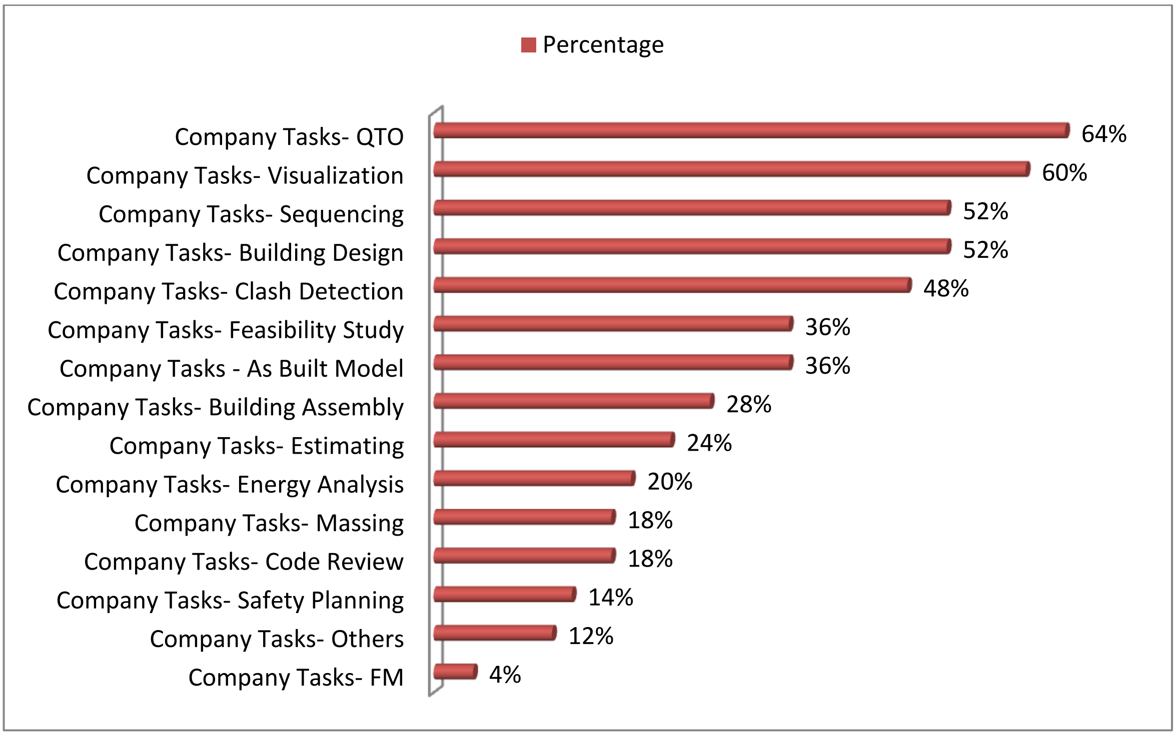

Figure 1: Tasks performed by respondent companies using BIM tools

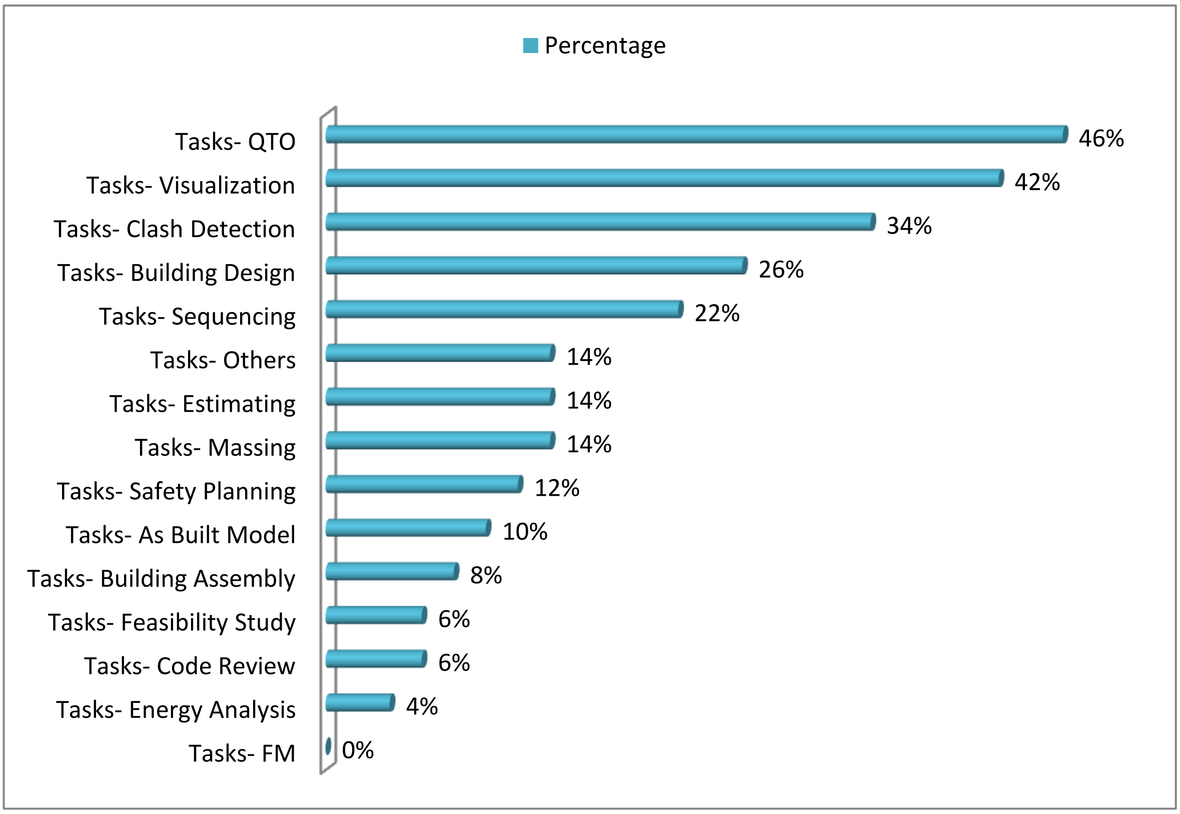

Figure 2: Tasks performed by respondents using BIM tools

Implications and Costs of BIM Implementation

A majority of respondents (56%) indicated that the physical space required remains unchanged but the majority of respondent companies (48%) indicated require more staff for the implementation of BIM, as depicted in Tables 4 and 5.

Variable	Percentage
Physical Space- Unchanged	56%
Physical Space- Less	24%
Physical Space- N.A.	8%
Physical Space- More	6%
Physical Space- Unknown	6%

Table 4: Physical space requirements for BIM implementation

Variable	Percentage
Staff- More	48%
Staff- Unchanged	36%
Staff- Less	8%
Staff- Unknown	4%
Staff- N.A.	4%

Table 5: Staff requirements for BIM implementation

Almost all respondents indicated that BIM implementation is in-house (86%) and only 14% of the respondent companies outsource for BIM – either fully or partially. Most BIM implementers (78%(bear the costs as well instead of passing on the relevant costs to other project stakeholders.

Benefits Derived from BIM

Most respondents surveyed (42%) do not know whether BIM has a positive or negative impact on the profitability of projects in their company. Reasons include their companies do not actively track the effects and ROI of BIM implementation. 24% of the respondents experienced an increase in profitability due to BIM, 26% indicated negligible changes and 8% witnessed a decline.

In terms of project-level benefits, the most commonly derived benefits from BIM implementations are *better information control* (72%), *less errors* (70%) and *improved communications* (60%). The most commonly gained company-level benefits are *better company image* (82%), *less mistakes and errors* (72%) and *strategic competitive advantage* (66%).

Figures 3 and 4 present the overall project- and company-level benefits respectively.

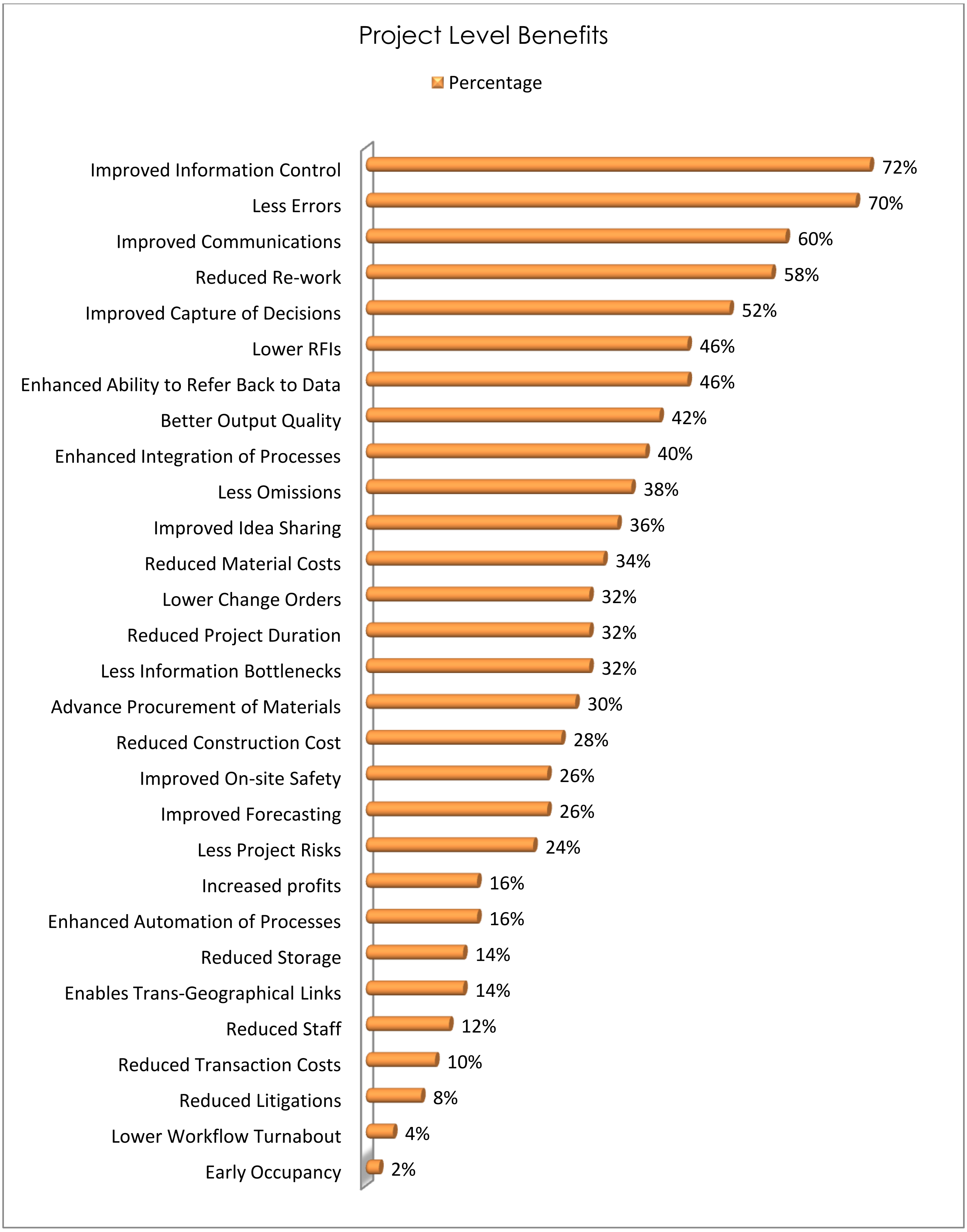

Figure 3: Project-level benefits derived from BIM

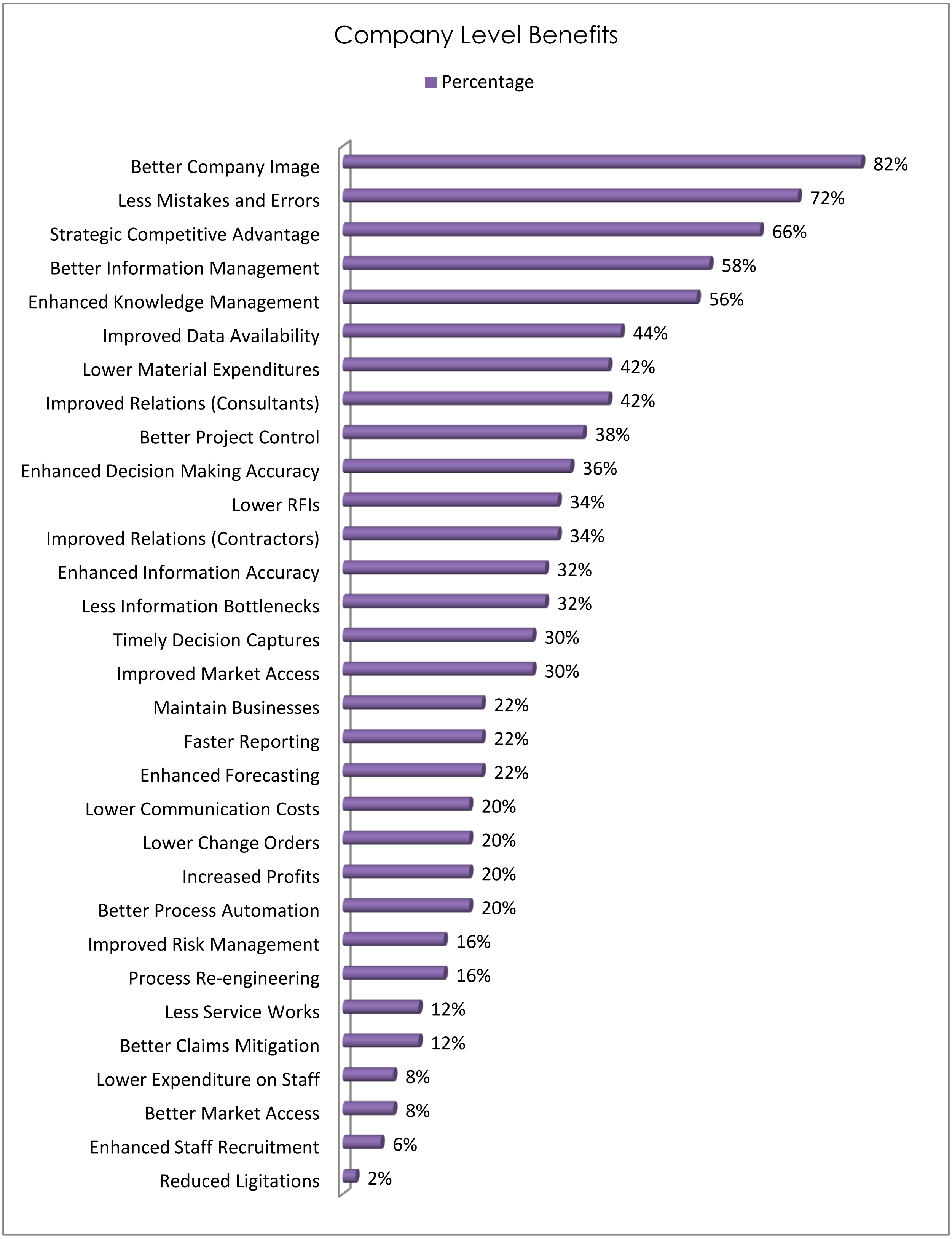

Figure 4: Company-level benefits derived from BIM

Business Value of BIM Implementations

From Table 6, one can infer that most respondents perceive "reduction in cost of BIM tools", "governmental incentives" and "readily available training" as the most crucial aspects to enhance the value of BIM and increase BIM benefits while "integration with mobile devices" is the least importance factor.

A test value of 3 is administered to a statistical t-test as it corresponds to a rating of "moderate" in the 5-point Likert Scale administered in the survey. All variables except "More BIM Researches" are statistically significant ($p < 0.05$) at a 0.05 significance level, as shown in Table 4.5

Variable	Mean Score	Sig. (2-tailed)
Lower Cost of BIM Tools	4.120	.000*
Government Regulations & Incentives	4.040	.000*
Readily Available Training	4.040	.000*
Clearly Defined BIM Deliverables	4.020	.000*
Internal Staff with BIM Skills	3.840	.000*
Better Functionality of BIM Tools	3.800	.000*
Entry-level Staff with BIM Skills	3.740	.000*
Developers Asking for BIM	3.720	.000*
Improved Inter-operability	3.700	.000*
More BIM Researches	3.220	.132
Integration with Mobile Devices	2.560	.006*

**Correlation is significant at the 0.05 level (2-tailed)*

Table 6: t-test analysis of the importance of various methods to improve value of BIM, in descending order of the mean

Experience Level and Change in Project Management Parameters

Experience Level of Users vs Changes in Project Aspects	Pearson Correlation, r Sig. (2-tailed), p
Years in Industry vs Change in Quality	-0.311* 0.028
Percentage of Projects with BIM vs Change in Quality	0.296* 0.037
Percentage of Projects with BIM vs Change in Safety	0.351* 0.012

**Correlation is significant at 0.05 level (2-tailed)*

Table 7: Correlation between experience level of users and change in cost, schedule, quality and safety of projects

The Pearson's correlation test analyzes the data obtained from the survey administered and three significant results are highlighted in Table 7.

There is a significant relationship between respondents' years spent in the industry and change in quality of projects (correlation coefficient = -0.311, p = 0.028). The negative relationship suggests that as users gain more experience in the industry, quality of projects after the implementation of BIM declines. This finding is unusual as one would generally expect quality to increase with higher experience levels. One possible reason may be that the learning curve of BIM being too steep for the older generations and/or the companies surveyed are at the initial stages of BIM implementation where they will witness a decline in productivity.

There is also a significant positive correlation between percentage of projects done with BIM and change in quality (correlation coefficient =0.296, p = 0.037) as well as change in safety (correlation coefficient =0.351, p = 0.012), implying that as the number of projects done with BIM increases, quality and safety of projects improve as well. This result is consistent with the findings of the SmartMarket (2009) report and supported by Succar (2010).

Experience Level and Project- and Company-Level Benefits

Experience Level of Users vs Project- and Company-Level Benefits	Pearson Correlation, r Sig. (2-tailed), p
Years in Industry vs Company Level Benefits	-0.310* 0.028
Percentage of Projects with BIM vs Company-Level Benefits	0.146* 0.031
Project Level-Benefits vs Company-Benefits	0.826* 0.000

**Correlation is significant at the 0.05 level (2-tailed)*

Table 8: Correlation between experience level of users and project- and company-level benefits

From Table 8, one can infer that users' years spent in the industry is negatively correlated to company-level benefits (correlation coefficient = -0.310, p = 0.028). This result may be due to senior managements' resistance to change to adopt and implement BIM technology or senior members of the companies being unable to overcome the learning curve/barrier for BIM. This trend is supported by Shennan (2012), who warned that the older generation may be left behind because of the technologies and working practices of BIM which are alien to them.

The results also show that company-level benefits increase as more projects are done with BIM (correlation coefficient = 0.146, p = 0.031). This indicates that users in the construction industry deepen their involvement with BIM as they began to see its benefits and will further capitalize on the BIM's potential to push for new methods to garner increased benefits.

For the results above, hypothesis 1 (where benefits and ROI which a company in the construction industry derives through the implementation of BIM is affected by experience level of BIM users and project managers in the company) is accepted.

Discipline of Users and Change in Project Management Parameters

		Change in Cost	Change in Schedule	Change in Quality	Change in Safety
Quantity Surveying	Pearson Correlation, r Sig. (2-tailed), p		.359* .020		
M&E Engineering	Pearson Correlation, r Sig. (2-tailed), p		-.362* .019	.355* .021	
Structural Engineering	Pearson Correlation, r Sig. (2-tailed), p	-.482* .002	-.314* .043		
Contractor (Main)	Pearson Correlation, r Sig. (2-tailed), p				.403* .008

**Correlation is significant at the 0.05 level (2-tailed)*

Table 9: Correlation between disciplines of users and change in project cost, schedule, quality and safety

From Table 9, one can infer that the discipline of quantity surveying will witness a longer duration in projects with BIM implementations (correlation coefficient = 0.359, p = 0.020). This may be due to a number of factors, including a longer learning curve and/or contractual issues that need to be resolved. M&E Engineers stand to benefit from BIM, as projects will experience an increase in quality (correlation coefficient = 0.355, p = 0.21) but a decrease in duration (correlation coefficient = -0.362, p = 0.019). In the traditional construction workflow, the building design is first completed, followed by structural and M&E design but BIM 'pushes' the M&E design processes forward (Lazarus, 2011). This allows for a reduction in time required for M&E works and also a higher level of quality, as clash detection tests done prior to construction can identify M&E design discrepancies at the early stages (Khanzode, et al., 2008).

There are negative significant correlations between structural engineering and changes in cost (correlation coefficient = -0.482, p = 0.02) and schedule (correlation coefficient = -3.14, p = 0.43). Collision detection may be one of the main reasons for the cost savings (Himes & Steed, 2008) as well as the reduction in time (Gijezen, et al., 2009).

Contractors gain improved safety in projects (correlation coefficient = 0.403, p = 0.008). This is support by the Associated General Contractors of America (2010), which mentioned higher reliability of expected field conditions due to BIM functionalities; Sulankivi and his team (2011) whom mentioned safety analysis procedures and space usage analysis with the use of BIM; and Rajendran & Clarke (2011) who stated the use of site traffic planning control with BIM for improved construction safety.

Therefore, Hypothesis 2 where different disciplines in the industry will achieve different benefits and ROI is accepted.

One Sample T-test for Project- and Company-Level Benefits

The one sample t-test establishes the statistically significant project- and company-level BIM benefits gained from the survey responses. This information will be utilized in the development of the proposed framework

A total of 19 out of 29 project-level benefits are found to be statistically significant ($p < 0.05$) and a total of 19 out of 31 company-level benefits were tested to be statistically significant ($p < 0.05$), as shown in Tables 10 and 11.

Project-Level Benefits	Sig. (2-tailed), p
Improved Information Control	0.000*
Enhanced Ability to Refer Back to Data	0.000*
Improved Idea Sharing	0.002*
Lower Workflow Turnabout	0.001*
Improved Communications	0.000*
Less Information Bottlenecks	0.009*
Enhanced Integration of Processes	0.000*
Better Output Quality	0.000*
Improved Capture of Decisions	0.000*
Less Errors	0.000*
Less Omissions	0.001*
Advance Procurement of Materials	0.017*
Reduced Project Duration	0.009*
Early Occupancy	0.001*
Reduced Construction Cost	0.031*
Lower RFIs	0.000*
Lower Variation orders	0.009*
Reduced Material Cost	0.004*
Reduced Re-work	0.000*

**Correlation is significant at the 0.05 level (2-tailed)*

Table 10: Compilation of t-test results for statistically significant project-level benefits

Company-Level Benefits	Sig. (2-tailed), p
Better Company Image	0.000*
Enhanced Knowledge Management	0.000*
Improved Market Access	0.017*
Strategic Competitive Advantage	0.000*
Improved Relations (with Contractors)	0.004*
Improved Relations (with Consultants)	0.000*
Less Information Bottlenecks	0.009*
Timely Decision Captures	0.017*
Improved Data Availability	0.000*
Better Information Management	0.000*
Enhanced Information Accuracy	0.009*
Enhanced Decision Making Accuracy	0.002*
Better Project Control	0.001*
Less Mistakes and Errors	0.000*
Lower Material Expenditures	0.000*
Lower RFIs	0.004*
Less Service Works	0.000*
Reduced Litigations	0.000*
Enhanced Staff Recruitment	0.027*

**Correlation is significant at the 0.05 level (2-tailed)*

Table 11: Compilation of t-test results for statistically significant company-level benefits

Linear Regression – Change in Cost of Projects

The linear regression technique is employed for the construction of models to determine the impact extent of BIM users' experience level and discipline on the cost of projects due to implementation of BIM, as cost is the main component in the calculation of ROI.

The derived regression models are:

Change in cost of projects = 0.164 – (1.085) (Years in Industry) – (0.025) (Percentage of Projects with BIM)

Change in cost of projects = 0.193 – (0.110) (Building Owner) – (0.110) (Architecture) + (0.049) (Quantity Surveying) – (0.006) (M&E Engineering) – (0.506) (Structural Engineering) + (0.037) (Project Management) + (0.022) (Main Contractor)

Multi-disciplinary Project Management Case Study

A multi-disciplinary project management case study were studied to further understand the investment costs of BIM and benefits that BIM confers

Project M1 is the first construction project (of its nature) in the country that boasts the first complete multi-disciplinary (all-in, with fittings) BIM model submission. This project follows the high standards of M2, a recently completed building with similar functionalities and fittings – but without the usage of BIM. These two projects serve as ideal cases for analysis and comparison. M1 is also slated to include special features like zero air infiltration and exfiltration and single-pass air system. A snapshot of the project details is provided in Table 12.

Description	M2 Building (without BIM)	M1 Building (with BIM)
Contract Type	PSSCOC	PSSCOC
Estimated Project Cost	S$256 million fully fitted	Not confirmed
Gross Floor Area	41,800 sqm	37,700 sqm
Level	15 Storey + 1 Basement	17 Storey + 1 Basement
Occupancy	Approximately 2,300	Approximately 2,100
TOP	July 2011	March/April 2015
Construction Period	27 Months	~27 Months
BCA GreenMark	Gold	Platinum
Software Used	AutoCAD	Revit 2010 (Archi, Struct, MEP)

Table 12: Details of Projects M1 and M2

The implementation of BIM resulted in the requirement of two additional staff during the design production stage, as shown in Table 13.

Task Assigned	M2 (without BIM)	M1 (with BIM)
Architects	2	2
Details	2	2
Coordination	1	1
Submission Preparation	1	1
2D CAD	2	0
Revit	0	4
Subtotal	8	10

Table 13: Comparison of staff required during design production stage in M2 and M1

Investments for BIM implementation throughout the company is done on a company level instead of project level and all upcoming projects handled by the company are slated to have mixed-teams comprising of experienced BIM users and new learners.

The key investments and the respective costs involved are listed in Table 14, showing that the investment cost per staff is approximately S$18,000 to S$30,000 – with the variation due to differences in salary-grade, scope of works as well as productivity.

The average learning curve for each staff to be sufficiently proficient in BIM software such as Revit is two months. It was also noted that the company has a dedicated IT (Information Technology) department with full-time specialists to assist and solve issues regarding hardware, software as well as connectivity.

Investments for BIM	Costs (per staff)
Hardware Upgrade (CPU + additional RAM)	~S$3,500
Software (Licensing)	~S$1,500
Training Fees Paid	~S$3,000
Production Downtime (Learning curve)	~S$6,000 to S$9,000 (2 Months' Salary)
Productivity Loss for Company	~2 Months (Downtime)
Subtotal	~S$18,000 to S$30,000

Table 14: Various investments placed and the costs involved.

Although this project management Company is an early adopted of BIM in the local context, it does not actively track ROI. The specific project-level benefits gained from BIM in the M1 project, potential benefits for future projects as well as potential issues faced are summarized in Table 15. The benefits gained fall largely in the category of project-level benefits which include improved information control, enhanced ability to refer back to data, reduced re-work and material costs.

Benefits Reaped from BIM for M1	Automated updates of plans once families are accurately set-up
	Reduced wastage and re-work
	Streamlined design process
	Straightforward pick-up of changes compared to traditional CAD
	Effective updating of files
	Enhanced visualization of project
	Minimized risk of discrepancies between plan, section and elevation
	Instant generation of new sections and elevations as well as odd corners
	Automated tagging with family, schedule and quantity generation
	Improved readability in drawings
	Minimized risk of interpretation differences in the multi-disciplinary collaboration

	Intelligent properties and components allow for extraction of information to enable more accurate cost estimation
Aspects Currently Being Explored by the Company	Improved collaboration with contractors
	Improved 'shop-drawing' submission and approval
	Streamlining BIM process the energy modeling
	Technicalities which includes schemes, options, hatching, site plan contour generation, hatching as well as line weight control
Potential Benefits to be Reaped	Improved procurement process with increased accuracy in automated quantity take-off process
	BIM model serving as a reference for building component manufacturers
	Published library parts (by component manufacturers) leading to faster and highly accurate model building
	Enhanced 3D coordination
	Shift from on-site, in-situ processes towards factory, pre-fabrication, automated, high-quality processes
	Improved As-Built documentation
	BIM model utilized for progressive 'shop-drawing' preparation and coordination
	BIM model utilized as a base for facilities management and life-cycle management and operations of facilities
Potential Issues Faced	Ownership of model – extent of sharing of model information
	Medium of exchange – especially if different set of software are used
	Clashes between various disciplines
	Decision maker for various processes
	Accuracy of documentation for submission

Table 15: Benefits reaped, expected issues as well as potential benefits to be reaped

A particular benefit under the category of *reduced materials* was reaped during the design production stage, which is shown in Table 16. More than 1000 copies of papers were saved due to BIM.

Printings Required	Quantity Saved (for M1)
A4 Specifications	600
A3 Details	300
A1 Drawings (200 per set)	3 Sets: 600

Table 16: Printing requirements saved for M1 project

Proposed BIM Benefits Optimization Framework

The aim of this self-assessment framework is to help companies identify the aspects which they are performing well, areas which can be improved, potential benefits to be gained and the plausible, incremental steps for improvement. Refer to Appendix A for the BIM Benefits Optimization Framework.

Development

The proposed framework builds upon the BIM capacity index (Succar, 2009), enabling qualitative analysis of BIM benefits which was not included in the original model. Capability maturity models originated in the field of quality management (Crosby, 1979) and they assist to identify a set of standardized process improvement levels to allow implementations to derive significant business benefits (Hutchinson & Finnemore, 1999).

The statistically significant project- and company-level benefits identified in the previous sections of this paper were adopted for the framework. The framework consists of two parts (A and B), to identify both project- and company-level benefits. A total of 38 benefits are listed, 19 each in Part A and Part B.

Application of Framework

The proposed BIM Benefits Optimization Framework is simple to use and applicable to all project managers and/or BIM implementers. It employs a 5-point Likert Scale representing the levels of “initial”, “defined”, “managed”, “integrated” and “optimized” respectively for each BIM benefit.

The steps for application are:

Step 1: Select the most applicable level (and note its corresponding score) for each benefit (row)

Step 2: Conduct the assessment for each project implemented with BIM using Part A of the BIM Benefits Optimization Framework (Project-Level Benefits)

Step 3: Conduct the assessment for the entire company using Part B of the BIM Benefits Optimization Framework (Company-Level Benefits)

Step 4: Compute the average score for each assessment by dividing the total score by the number of benefits listed in each part of the framework.

Step 5: Compute the total score for the company using the equation:

$$Total\ Score = (P_1 + P_2 + P_3 + \dots P_n)/n + C$$

Where:

n = number of projects in the company implemented with BIM

P = Project Score (average score for a particular project using Part A of the framework)

C = Company Score (average score for the company using Part B of the framework)

Unique Benefits of Framework

The framework is an innovation which takes into account both BIM maturity level and benefits at project- and company- levels. The incremental levels and descriptions also serve to assist assessors on how certain areas can be improved. The computed total score can be utilized for indexing or benchmarking against past years to determine improvements. Individual project-level scores can also be compared across all projects in the company to identify weak aspects to be improved. Furthermore, the framework is flexible as individual assessors or companies can add other benefits or remove particular rows (benefits) which are not applicable.

Proposed BIM ROI Cash Flow Formula

The formula aims to help companies determine the annual financial impact of BIM implementations and the associated payback period, taking into account all major cost components and the changes in cost of BIM-implemented projects due to the experience level of users.

Development

Various ROI calculation methods were studied, including generic ROI formulas, the BIM ROI formula proposed by Autodesk (2007), the equation for engineering productivity by Sacks (2006) and the BIM ROI Calculator proposed by Ideate BIMLink. However, none of the formulas were found to include sufficient parameters to be an adequate ROI and/or cash flow predictor.

The coefficients for the independent variables "years in industry" and "percentage of projects with BIM" were obtained from the regression models in this paper, while the cost of each workstation, including hardware, software and training is the average value obtained from the case study.

Application of Formula

The annual financial impact of BIM implementations can be computed through the utilization of the following set of equations.:

$$\text{Cash Flow (CF) in year } k = (\Delta_i)i_0 - \Delta_c - (n_{3Dk} - n_{3Dk-1})(C_{3D}) - (n_{3Dk})(m_{3D}) - n_{2Dk}(m_{2D}) - [(n_{ak})(L_a) + (n_{mek})(L_{me}) + (n_{sek})(L_{se}) + (n_{pmk})(L_{pm}) + (n_{qsk})(L_{qs})] + (S_p \quad (1)$$

$$\Delta_c = (1 - 0.025P_k)(C_0) \quad (2)$$

$$n_{3Dk} = (n_{ak} + n_{sek} + n_{mek} + n_{pmk} + n_{qsk}) / (P_k) \quad (3)$$

$$n_{2Dk} = (n_{ak} + n_{sek} + n_{mek} + n_{pmk} + n_{qsk}) / (1 - P_k) \quad (4)$$

$$S_p = (1.085)(Y)\,(0.025)(P_k)(C_0) \quad (5)$$

Where:

k	= the number of years after initial investment in BIM implementations
Δ_i	= forecast growth in income by year k / current income
i_0	= current annual income for all projects
Δ_c	= adjusted annual overhead costs with savings derived from BIM computed
C_0	= current annual overhead costs
P_k	= percentage of projects with BIM usage; $0 \leq P_k \leq 1$
n_{3Dk}	= number of BIM enabled workstations
n_{2Dk}	= number of normal workstations without BIM capabilities
C_{3D}	= investment cost of a BIM-enabled workstation (including hardware, software and training)
m_{3D}	= annual maintenance costs of 1 BIM enabled workstation
m_{2D}	= annual maintenance costs of 1 normal workstation without BIM capabilities
n_{ak}	= number of architects in year k
n_{me}	= number of M&E engineers in year k
n_{se}	= number of structural engineers in year k
n_{pm}	= number of project managers in year k
n_{qs}	= number of quantity surveyors in year k
L_a	= average salary per annum for architectural work
L_{me}	= average salary per annum for M&E engineering work
L_{se}	= average salary per annum for structural engineering work
L_{pm}	= average salary per annum for project management work
L_{qs}	= average salary annum for quantity surveying work
S_p	= savings due to productivity gain as experience level of users increase
Y	= increased years in industry of all staff from previous year

The use of the formula is illustrated using an example of a typical construction consultancy project management department X in Table 18. In this department, the implementation of BIM is gradual and the total capital outlay for BIM is S$360,000, including procurement of hardware, software, training and support. The payback (break-even) period is attained in approximately 3 years.

From the break-even point in Year 3, savings due to productivity gain increases exponentially. However, the law of diminishing returns sets in in the fifth year and savings increased only slightly, before hitting a consistent level.

As illustrated in Table 18, the department decided to implement BIM on 30% of the Projects in the first year of adoption and the resulting impact is an increase in the number of staff required – as the department retains 2D CAD production units to meet project and contractual requirements while adopting 3D modeling concurrently. The process are streamlined as more projects are done with BIM, cutting down on inefficiencies and redundancies, ultimately witnessing a reduction in 2D CAD drafters, old workstations but an increase in productivity and net revenue.

Unique Benefits of Formula

The BIM ROI Cash Flow Formula is an elaborated formula, compared to others. It takes into account many important variables and parameters, including cost of investments, salary of staff from various disciplines and savings resulting from improved productivity and experience to predict cash flow of new BIM implementers on an annual basis, enabling companies to track the major cost components and net revenue/loss.

	Year 0 (Initial Stage)	Year 1	Year 2	Year 3	Year 4
Staff Employment Allocation					
No. of Architects/Revit Arch.	2	4	4	4	4
No. of M&E Engineers	2	3	3	3	3
No. of Structural Engineers	2	3	3	3	3
No. of Quantity Surveyors	3	3	2	2	2
No. of Project Managers	1	1	1	1	1
No. of 2D CAD Drafters	8	8	6	4	2
Subtotal	18	22	19	17	15
Input Variables					
Percentage of Projects with BIM	0	0.3	0.6	0.9	1
Workstations					
Workstations (Normal/Old)	18	15	8	2	0
Workstations (3D BIM Capable)	0	7	11	15	15
Income/Inflow - ($1,000)					
Income*****	2,000	2,060	2,122	2,185	2,251
Costs/Outflow - ($1,000)**					
Architecture Staff	81.6	168	168	168	168
M&E Engineering Staff	67.2	100.8	100.8	100.8	100.8
Structural Engineering Staff	67.2	100.8	100.8	100.8	100.8
Quantity Surveying Staff	90	90	60	60	60
Project Management Staff	54	54	54	54	54
Drafting Staff	192	192	144	96	48
Newly Procured BIM Workstations*	0	168	96	96	0
Maintenance (Normal Workstation)****	18	15	8	2	0
Maintenance (BIM Workstation)***	0	14	22	30	30
Fixed Overheads	300	298	294	287	280
Savings from Productivity Gain	0	-44	-91	-133	-144
Total Operating Costs	870	1156.6	956.6	861.6	697.6
Total Cash Flow					
Net Revenue/Losses	1,130	903	1,165	1,324	1,553
Change from Base Year	0	-227	35	194	423

**cost of each BIM workstation (including software, training etc) is the average value obtained from Case Study One*

***average salary is obtained from BCA's Built Environment Career Guide with the upper limits utilized*

****maintenance of BIM enabled workstation is assumed to be approximately S$2,000/annum*

*****maintenance cost of normal workstation is assumed to be approximately $1,000/annum*

******inflation rate is assumed to be 3% per annum*

Table 17: BIM implementation cash-flow of Department X using proposed formula

Conclusion

Based on this study, several concluding recommendations are offered to project managers operating in the construction industry.

BIM is not a panacea for a lack of productivity, lack of experience or lack of knowledge. It is integral that a company must be able to establish a productive and efficient link between the core competencies of its practice and the use of BIM to successfully derive benefits.

Second, the transition to BIM is not as simple as uninstalling AutoCAD and installing Revit. The paradigm shift requires an overhaul involving new learning curves, time to develop resources like libraries and families, process re-development and staffing amendments. Companies and project managers cannot be afraid to make changes.

Lastly, the tracking of ROI and measurement of benefits derived from BIM will definitely enhance firms' BIM processes and ultimately, productivity and efficiency in the long run. Measurements can be benchmarked against data from the previous years to unearth new improvements for old processes.

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BIM BENEFITS OPTIMIZATION FRAMEWORK

		BIM Benefits Optimization Framework Part A				
		Project Level Benefits				
		Level 1 - Initial	Level 2 - Defined	Level 3 - Managed	Level 4 - Integrated	Level 5 - Optimized
	Score / Benefit	10	20	30	40	50
New Frontiers	Improved information control	Stakeholders lack infrastructure to harvest and share information	Information infrastructure system is available but slow and dispersed	Content and asset management tools are deployed to regulate information	Information management system deployment follows strategic project objectives	Information management system is proactively enhanced and upgraded
New Frontiers	Enhanced ability to refer back to data	BIM model information is utilized on an ad-hoc basis	BIM model information is documented, stored and harvest	Detailed process plan is available for BIM model information data repository system	BIM information data repository system is aligned with project goals and objectives	BIM information and data repository system is constantly upgraded and enhanced to keep up with projects goals
Increased Value	Improved idea sharing	Each department is run independently	Collaboration between different disciplines and departments is managed through ad-hoc alliances	Each project team member thinks beyond the particular project	Team member roles are integrated into organization's structure	Team members constantly share ideas and contributes to organization, beyond particular project

	Lower workflow turnabout	Project team members utilized BIM model information on an ad-hoc basis	Project team members have specifically assigned BIM process workflow	Detailed BIM information, deployment plan, and workflow allocation is available	Detailed BIM information and deployment plans is aligned with project objectives and manpower allocation	Detailed BIM information and deployment plans are constantly evaluated, updated and enhanced
	Improved communications	Information exchanges suffer from a lack of inter-operability	Interoperable data exchanges are defined and prioritized	Data flow is well managed, mandated and closely monitored	Interoperable data exchange and usage are performed as part of overall project strategy	Interoperable data exchange system is proactively enhanced
	Less information bottlenecks	BIM information is shared on an ad-hoc or informal basis	BIM information is shared systematically or in accordance to specific processes	Detailed BIM information management plan are available	BIM information and management plans are aligned with project objectives and goals	BIM information and management plans are continuously evaluated and upgraded for productivity
	Enhanced integration of processes	Object-based tool with no process changes	BIM process and policy requirement plans are prepared	BIM integration plans and processes and standardized and control	BIM integration plan, technologies, processes are integrated and aligned with project objectives	BIM integration plans and processes and continuously enhanced to achieve higher performance targets

	Better output quality	3D model deliverables suffer from detail inconsistencies	Details defining the requirements of the model is provided	3D model provides accurate details which follows prescribed standards	3D model provides accurate details, follows prescribed standards and meet project goals	BIM model system and products and constantly evaluated and enhanced
	Improved capture of decision	Decision making by project team members is unaffiliated to BIM model information	BIM model information is utilized on ad-hoc basis for simple decision makings	Decision making plan and processes are available and integrated with BIM model information	BIM model information is integrated with project decision making to meet project objectives	Integration of BIM model information with project decision making is regularly evaluated and enhanced
	Less errors	BIM software is not integrated with project and information is used on an ad-hoc basis	BIM model information is utilized in the projects phases for simple identification and flagging	Detailed plan available to integrate BIM model information with project phases	BIM model information is integrated with project objectives, resulting in reduction of errors	Integration of BIM model information with project stages is constantly reviewed and enhanced to minimize errors
	Less omissions	BIM software is not integrated with project and information is used on an ad-hoc basis	BIM model information is utilized in the projects phases for simple identification and flagging	Detailed plan available to integrate BIM model information with project phases	Integration of model information with project objectives, resulting in reduction of omissions	Utilization and integration of BIM model information with project stages is constantly reviewed and enhanced

	Advance procurement of materials	BIM model information is not integrated with procurement management and information is used on an ad-hoc basis	BIM model information is utilized in the project for simple procurement management	Detailed plan available to integrate BIM model information with project procurement management	BIM model information is integrated with procurement management to meet project procurement objectives	Integration of BIM model information with procurement management is constantly reviewed and enhanced for advance procurement
Savings	Reduced overall project duration	BIM model information is not integrated with schedule management and information is used on an ad-hoc basis	BIM model information is utilized in the project for simple schedule management	Detailed plan available to integrate BIM model information with project schedule management	BIM model information is integrated with schedule management to meet project schedule objectives	Integration of BIM model information with schedule management is constantly reviewed and enhanced for reduction in schedule
	Early occupancy	BIM model information is not integrated construction schedule management and information is used on an ad-hoc basis	BIM model information is utilized in the project for approximate gauge of occupancy schedule	Detailed plan available to integrate BIM model information with occupancy management	BIM model information is integrated with occupancy management to meet project schedule objectives and early completion	Integration of BIM model information with occupancy management is constantly reviewed and enhanced for early occupancy

	Reduced construction costs	Construction cost management is not integrated with BIM model information	BIM model information is utilized in project phases for simple construction cost estimation	Detailed plan available to integrate BIM model information with construction cost management	BIM model information is integrated with construction cost management to meet project cost objectives	Integration of BIM model information with cost management is constantly enhanced for reduction in construction costs
	Lower number of RFIs	BIM RFIs are not tracked and BIM model information is used on an ad-hoc basis	BIM RFI data is arbitrary and informally managed	Detailed BIM RFI management plan is available and project witness lower unnecessary RFIs	Detailed BIM RFI management plan is aligned with project goals and objectives	Detailed BIM RFI management plan is continuously evaluated and enhanced for greater productivity
	Lower number of VO (variation orders)	BIM VOs savings are not tracked	BIM VO savings data is arbitrary and informally managed	Detailed BIM VO savings plan is available and project witnesses low/no unnecessary VOs	Detailed BIM VOs savings plan is aligned with project goals and objectives	Detailed BIM VOs savings plan is continuously evaluated and enhanced for greater productivity
	Reduced costs of materials	BIM material cost savings is not tracked on a project level	BIM materials cost savings data is arbitrary and informally managed	Detailed BIM material cost savings plan is available and project derived actual cost savings	Detailed BIM material cost savings plan is aligned with project goals and objectives	Detailed BIM material cost savings plan is continuously enhanced for greater productivity

	Reduced Re-work	Redundant and excessive work is not measured and BIM does not affect workflow	BIM information is used to reduce redundant work on an ad-hoc basis	Detailed BIM workflow and process plan is available and plan is used to reduce unnecessary re-work	Detailed plan is integrated with BIM process as well as project goals and objectives	Detailed plan is constantly evaluated and enhanced for greater reduction of re-work

		BIM Benefits Optimization Framework Part B				
		Company Level Benefits				
		Level 1 - Initial	Level 2 - Defined	Level 3 - Managed	Level 4 - Integrated	Level 5 - Optimized
Score / Benefits		10	20	30	40	50
New Frontiers	Better company image	BIM usage is implemented simply because of client's request	BIM usage implementation is marketed and integrated with company's core competencies	Detailed plan for BIM integration with company processes. Marketing of BIM capabilities is available	BIM integration and marketing is aligned with company's goals, objectives and projects in the pipeline	BIM integration and marketing plan is constantly reviewed and enhanced for optimization
	Enhanced knowledge management	Knowledge management system is ad-hoc or non-existent	Knowledge management system is identified within company	Knowledge management system is detailed and solutions for harvesting, storing and sharing knowledge is adequate and accessible	Knowledge management system enabling multiple facets of the BIM process to be integrated available and aligned to company objectives	Knowledge management system solutions are constantly assessed and improved for optimization and enhanced accessibility

	Improved market access	Senior Managements have shared varied visions about BIM and market access plans	Senior managements have common vision about BIM and market access but lack actionable detail	Vision to implement BIM and plans for greater market access is well understood and communicated with detailed action plans and monitoring system	Vision for BIM implementation and market access is shared by staff across the company and integrated into company's objectives	Company staff and stakeholders have internalized BIM implementation and market access plans and are already actively achieving it
	Strategic competitive advantage	BIM infrastructure is inadequate and usage of BIM software is utilized only to meet client's requirements	BIM infrastructure is adequate and BIM processes implemented in projects helmed by the company	BIM Infrastructure and process plan is available and management willing to integrate BIM to improve company processes and value-add to clients	BIM process plan and is integrated and aligned with company goals and objectives as well as value-add to clients	BIM process plan and is constantly reviewed and enhanced for optimization of value-added benefits to clients

	Improved relationship with contractors	Company and contractors run independently on a project or ad-hoc basis	BIM requirements are recognized by company and contractors	Collaboration between company and contractors over several projects are managed through temporary alliances	Collaborative BIM approach is undertaken by company with contractors and aligned through trust and mutual dependency beyond contractual barriers	Responsibilities, risks and rewards and continuously revisited and realigned to optimize the collaborative relationship between company and contractors
	Improved relationships with consultants	Company and consultants run independently on a project or ad-hoc basis	BIM requirements are recognized by company and consultants	Collaboration between company and consultants over several projects are managed through temporary alliances	Collaborative BIM approach is undertaken by company with consultants and aligned through trust and mutual dependency beyond contractual barriers	Responsibilities, risks and rewards and continuously revisited and realigned to optimize the collaborative relationship between company and consultants
Increased Value	Less information bottleneck	BIM information is shared on an ad-hoc or informal basis	BIM information is shared systematically or in accordance to specific processes	Detailed BIM information management plan for company is available	BIM information and management plan is aligned with company objectives and goals	BIM information and management plans is continuously evaluated for productivity

	Timely capture of decision	Decision making by company staff is unaffiliated to BIM	BIM information is utilized on an ad-hoc basis for simple decision makings	Decision making plan and processes are available and integrated with BIM processes	BIM processes are integrated with decision making to meet company objectives	Integration of BIM processes with decision making is regularly evaluated and enhanced
	Improved data availability/accessibility	Staff lack BIM infrastructure to harvest and share information	Information infrastructure system is available but slow and dispersed	Content and asset management tools are deployed to regulate information	Information management system deployment follows strategic company objectives	Information management system is proactively enhanced and upgraded
	Better information management	Information management is done the traditional way and not used with BIM	Information is used with BIM on an ad-hoc basis	Detailed plan managing and integrating the use of information with BIM is available	Detailed plan is aligned with company's processes and strategic goals	Detailed plan is continuously revisited and enhanced for better information management within company
	Enhanced accuracy and validity of information	Information management is done the pre-BIM way and is not integrated with BIM	BIM is utilized for simple validation of information on an ad-hoc basis	Detailed plan integrating the use of BIM and validation of information is available	Detailed plan managing BIM information validation is aligned with company's strategic operations and goals	Detailed plan is continuously revisited for enhancements in accuracy and validity of information from BIM

	Enhanced accuracy and validity in decision making	Decision making in the company is neither affected nor integrated with BIM usage	BIM is utilized for simple decision making	Detailed plan integrating the use of BIM and decision making processes is available	Detailed plan for decision making in the company is aligned with company's strategic goals and objectives	Detailed plan is constantly evaluated and enhanced for greater accuracy and validity
	Better project/program control	Use of BIM tools is unregulated and on an ad-hoc basis in the company	Use of BIM tools is unified within company	Detailed plan managing use of BIM tools and integration with project control is available	Detailed plan for integration with project control is aligned with company's goals and objectives	Detailed plan is continuously revisited for enhancements in project control
	Less mistakes and errors	BIM software is not integrated with projects and information is used on an ad-hoc basis	BIM information is utilized in company's projects for simple identification and flagging	Detailed plan available to integrate and unify BIM information with company's projects	BIM model information is integrated with company objectives, resulting in reduction of errors	Integration of BIM model information with company's processes is constantly reviewed and enhanced to minimize errors
	lower expenditure on materials	Material expenditure attributed to BIM is not tracked on a company basis	Material expenditure (attributable to BIM) data is arbitrary and informally managed	Material management and expenditure plan is utilized to derived actual cost savings	Detailed material management and expenditure plan is aligned with company goals and objectives	Detailed material management and expenditure plan is continuously enhanced for greater cost savings

	Lower number of RFIs	RFIs attributable to BIM are not tracked and BIM model information is used on an ad-hoc basis	BIM RFI data is arbitrary and informally managed	Detailed BIM RFI management plan is available and company witness lower unnecessary RFIs over projects	Detailed BIM RFI management plan is aligned with company goals and objectives	Detailed BIM RFI management plan is continuously evaluated and enhanced for greater productivity
	Less service works required	Service works attributable to BIM are not tracked	Service works attributable to BIM is managed on an ad-hoc basis	Detailed plan charting the service works attributable to BIM is available, Company attempts to reduce unnecessary service works through BIM	Detailed plan to reduce unnecessary service works through BIM is aligned with company objectives and goals	Detailed plan to reduce unnecessary service works through BIM is constantly reviewed and enhanced for greater productivity
	Reduced litigations/arbitrations	Dependence on pre-BIM contractual agreement across projects	Recognition of BIM requirements and information defining responsibility of each stakeholder is available	Mechanism to manage shared BIM intellectual property, liability and confidentiality is available	Stakeholders are aligned through trust beyond contractual barriers and system for BIM conflict resolution is available in the company	BIM responsibility, risks and conflict resolution system are constantly realigned in the company for enhancement and reduced contractual issues

	Enhanced recruitment of staff	Absence of defined processes. Roles are ambiguous with inconsistent team structure	BIM roles are formally defined and teams are formed accordingly. BIM competency is identified and targeted	Cooperation within the company increases as tools for cross-projects communication are made available	BIM roles and competency targets are imbedded within the organization and traditional teams are replaced with BIM-oriented ones	BIM competency targets are constantly evaluated with recruitment of staff to ensure intellectual capital matches company needs