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The Return on Investment from BIM-driven Projects in Construction

Neelamkavil, J.; Ahamed, S.S.

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The Return on Investment from BIM-driven Projects in Construction

Summary

The measuring of the business value of BIM has attracted the attention of various stakeholders in the construction industry. Yet, there has been a lack of consistent, cost-benefit benchmarking associated with the introduction of BIM technology. Return of investment (ROI) analysis is one of many ways that is used to evaluate any proposed new investment. The availability of cost-benefit information will be of prime importance for professionals in the construction industry trying to adopt newer technologies, especially BIM. Calculating the ROI attributable to adopting BIM will help those involved to come up with an understanding on why the money is being spent, and what the expected benefits are. It compares the gains anticipated from an investment against the cost of such investment. Apart from dollars spent, BIM's implementation requires championing the cause, persistence and planning.

This report is about how the ROI has been interpreted and compiled by a number of construction companies that have utilized BIM in their projects. Based on real life construction data, the perceived value of BIM has been derived. It focuses on quantifiable benefits as well as the costs associated with BIM's usage at the project level. Our study concludes that companies, in general, use dissimilar metrics for measuring the ROI, which includes qualitative measures also. This study pins down tangible ROI measures, quantitative in nature, which may be used by most companies contemplating the use of BIM.

1. The ROI from BIM

The measuring of the business value of BIM has attracted the attention of many builders and construction practitioners. Yet, there has been a lack of consistent, cost-benefit benchmarking associated with BIM process innovations. The availability of cost-benefit information will be of prime importance for professionals in the building industry trying to adopt newer technologies. Calculating the return on investment (ROI) attributable to introducing BIM technology will help those involved to understand why the money is being spent, as well as what the expected results are. ROI analysis is one of many ways that is used to evaluate any proposed investment. It compares the gains anticipated from an investment against the cost of the investment. BIM's implementation requires championing the cause, persistence and careful planning.

The value proposition of BIM is not just the static benefits realized during the execution of a single project. The knowledge and experience gained from one BIM driven project will be beneficial and reusable in almost all future projects. Further value runs along the complete lifecycle aspects of construction, which includes the design, construction, operation and maintenance of the facility. But, since the projects that have made use of BIM are relatively recent, there may not be sufficient data available to measure or elaborate on the lifecycle benefits of the use of BIM. It also means that the true manner of BIM's return can be computed only after all the downstream activities have been fully considered. Further, to consider all activities of construction - from inception to demolish – thereby computing the true nature of the ROI, may prove to be quite a major task.

In measuring the ROI associated with BIM, three factors become apparent -- direct costs, the benefits realized during the project, and the returns (i.e. profit). The direct cost includes software, hardware, its maintenance, staffing and training; the benefits include savings realized due to the reduction in delivery charges, travels, reduction in the project's total duration and improved scheduling attributable to the BIM process; the overall returns include the increase in profits. Case studies noted below have examples of many of these, illustrated in one form or other.

The purpose of the studies reported in this report is to understand the perceived value of BIM in the construction industry, as seen by the practitioners in this sector. It focuses on quantifiable benefits and the costs associated with BIM's usage at the project level. Progress in adapting to BIM seems slow, but certain. A simple formula that is often equated to the return on investment is:

ROI = Earnings/Cost

The figure below [Ref: 10] illustrates what happens after a new technology (such as BIM) has been introduced. There's an immediate dip in productivity as the users get up to speed on the new system. With time, productivity climbs back to where it was with the original system and levels off at a higher point as the new technology takes effect. Taking these into consideration, we have examined a number of case studies in regard to BIM's perceived returns. The results show improvement in design quality, in terms of error-free drawings, and steadily increasing improvement in labour productivity.

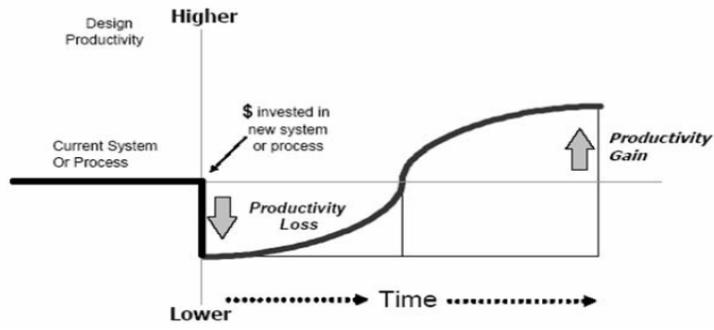


Figure 1: Change in productivity resulting from technology introduction [Source: Autodesk Web Page - Ref: 10]

2. The Case Studies

The BIM process allows the project participants to communicate and collaborate; it is expected to incur greater efficiency both at the office and at the construction site, higher quality and speed in decision making, as well reduced conflicts. The case studies elaborated below show that BIM has a direct impact on construction productivity. Typically, the higher the productivity, the greater the profit realization and this will lead to a quicker realization of the ROI.

2.1 McGraw Hill Report

Though the construction industry has been confronted with a down economy in recent years, as per McGraw Hill report [Ref: 1], most BIM users have seen positive payback from their use of the technology. Users have realized some of the greatest value of BIM through its influence on cutting down on rework, like rekeying information into models, or making changes in the field. The users gain a range of benefits that include better productivity, enhanced quality, new business opportunities, overall better project outcomes, and improve their ability to integrate teams and give them an edge on the competition. Key findings, based on McGraw Hill show that with the use of BIM:

- Two-thirds of the users state they have seen positive ROI on their investment.
- 87% of expert users are experiencing positive ROI.
- 93% of the users believe there is potential to gain more value from it in the future.

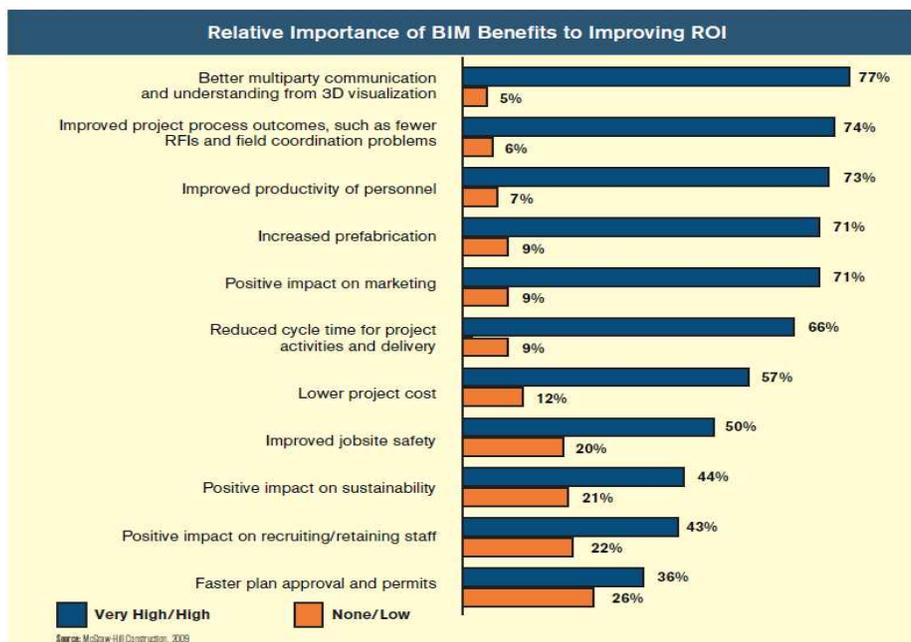


Figure 2: BIM's role in improving productivity [Source: McGraw Hill Report - Ref: 1]

Other findings:

- The returns improve with experience
- Owners and contractors see the highest returns on BIM
- Nearly all users believe there are greater future opportunities to gain value from BIM
- Top rated areas of BIM investment are: 1) software, 2) developing internal collaborative BIM procedures, 3) marketing BIM capability, 4) BIM training, 5) new/upgraded hardware

BIM opens all sorts of doors for construction companies. As more clients begin to require BIM on their projects, the team members will need BIM skills to capture that business. On the flip side, companies can introduce the technology to new clients and use it as a marketing feature, thereby getting a leg up in their bid to land a job. McGraw Hill reports several case studies.

Case Study 1: \$201 million Research 2-project for the University of Colorado, Denver Health Sciences Center -- 11-story 540,000 square-foot biomedical facility.

It led to a reduction in construction RFIs of 74% during the foundation phase and 47% during the steel erection phase. Overall, the project experienced a 37% reduction in coordination of request for information (RFI) and a 32% reduction in coordination of change orders compared to a comparable project. Notable schedule gains were also realized. Completed in June 2008, this project was progressing two months ahead of schedule and six months ahead of another comparable project. The project team estimated a 50% reduction in both labour and the work schedule due to the BIM driven approach.

Case Study 2: \$103.5 million Texas A&M Health Science Center.

Satterfield & Pontikes Construction completed this project satisfactorily within budget and BIM played a key role in this achievement. Note that this project was initially awarded to a different party, who was targeting for higher than budgeted cost.

Case Study 3: \$320 million Sutter Health Medical Center Castro Valley.

BIM and BIM-related tools played a vital role in this project. The design of all systems was performed and coordinated using 3D modeling software. By the time the ground was broken, the project team had produced over 25,000 electronic design documents. With hundreds of team members located across the US, more than 50 companies creating the files have access to real time data from any location. Although a lot of time had been spent early in the planning phase, it outpaced projects executed under traditional delivery methods. The overall budget against actual spending for the preconstruction costs is reported to show a savings of over \$1.2 million.

Case Study 4: Department of Energy - \$100 million, 45,000 sq.-foot explosives pressing facility.

BIM enabled a clash detection feature that identified thousands of collisions. Virtually “walking through” every room in the facility, the staffs have uncovered over 500 serious problems. Independent cost estimators calculated a \$10 million savings generated by the modeling effort.

2.2 Aquarium Hilton Garden Inn – Atlanta

Holder Construction made a strategic decision to integrate BIM for its Aquarium Hilton Garden Inn project (Ref: 2) - a \$46 million project consisting of the construction of a 484,000 square foot facility. The intent was to apply BIM technologies across the entire team in a way that was effective for this development which consisted of a 14-story, 242 room hotel, a 700 vehicle parking structure, and 25,000 square foot of retail space at the ground level.

In spite of the fact that many team members were totally new to BIM technology, 55 clashes were identified during the design development stage alone, resulting in the avoidance of RFIs for the project. The resolved collisions were tracked with an effective cost avoidance of \$124,500. This stage yielded a savings return of \$84,500 on the original \$40,000 BIM expense. At the construction documentation phase the model was updated and the resolved collisions were tracked. Each critical clash was shared with the design team via the model viewer and a numbered collision log. Over 590 clashes were detected via the BIM software. The overall cost savings were estimated at \$800,000 (see the spreadsheet below). Another BIM advantage realized by Holder during the construction phase was in the code official review. Because of the detail level of the 3D model, city building officials could easily understand the design concept and conduct code reviews in a timely manner.

Collision Phase	Collisions	Estimated Cost Avoided	Estimated Crew Hours	Coordination Date
100% Design Development Conflicts	55	\$124,500	NIC	<i>June 30, 2006</i>
Construction (MEP Collisions)				
Basement	41	\$21,211	50 hrs	<i>March 28, 2007</i>
Level 1	51	\$34,714	79 hrs	<i>April 3, 2007</i>
Level 2	49	\$23,250	57 hrs	<i>April 3, 2007</i>
Level 3	72	\$40,187	86 hrs	<i>April 12, 2007</i>
Level 4	28	\$35,276	68 hrs	<i>May 14, 2007</i>
Level 5	42	\$43,351	88 hrs	<i>May 29, 2007</i>
Level 6	70	\$57,735	112 hrs	<i>June 19, 2007</i>
Level 7	83	\$78,898	162 hrs	<i>April 12, 2007</i>
Level 8	29	\$37,397	74 hrs	<i>July 3, 2007</i>
Level 9	30	\$37,397	74 hrs	<i>July 3, 2007</i>
Level 10	31	\$33,546	67 hrs	<i>July 5, 2007</i>
Level 11	30	\$45,144	75 hrs	<i>July 5, 2007</i>
Level 12	28	\$36,589	72 hrs	<i>July 5, 2007</i>
Level 13	34	\$38,557	77 hrs	<i>July 13, 2007</i>
Level 14	1	\$484	1 hrs	<i>July 13, 2007</i>
Level 15	1	\$484	1 hrs	<i>July 13, 2007</i>
Subtotal Construction Labor	590	\$564,220	1143 hrs	
20% MEP Material Value		\$112,844		
Subtotal Cost Avoidance		\$801,565		
Deduct 75% assumed resolved via conventional methods		(\$601,173)		
Net Adjusted Direct Cost Avoidance		\$200,392		

Table 1: Savings due to the usage of BIM [Source: Aquarium Hilton Garden Project - Ref: 2]

2.3 BIM Adoption for Precast Concrete Design

Kassian Dyck & Associates ('KD&A') is a privately owned mid-sized structural engineering firm in Calgary, Canada; whereas, The Star Engineers Ltd. ('Star') is a consulting structural engineering firm, which is also privately owned. The benefits achieved by these firms in adapting to BIM are presented in the form of two case studies [Ref: 3]. Each company began with a project in which it was responsible for only a part of the structure, and then progressed to a total precast structure. The KD&A designed the first two: the Blackfoot Museum project required the design of precast façade panels with complex piece geometries, and the Eagle Ridge project, a large scale residential apartment with multiple total precast structure buildings. The second set of two projects were designed by the Star: the Modi'in commercial centre involved the design of precast concrete beams with curved geometry that carried

hollow-core slabs in a cast-in-place structure, and the Shelter project, a total precast single story building.

KD&A realized that BIM could be used to review potential conflicts or project complications within the model; these could be discovered and resolved easily prior to issuing drawings for construction. The use of the BIM also reduced the possibility of misaligned connections, incorrect architectural features, and geometry conflicts, so that shop drawings could be created without the need for detailed checking or cross coordination between drawings. Star’s objectives in adopting BIM were somewhat similar to those of KD&A, in terms of productivity and error reduction, but there were also some differences, for example: problems related to design and drafting errors that led to problems of mismatched pieces and connections in the field; low productivity in preparing shop drawings (especially where design changes were frequent); and long cycle times for design reviews – all of which led the firm’s senior engineers to consider BIM as a means to improve their precast design service.

Star was responsible for the detailed design of the precast elements for the parking structure associated with the Modi’in commercial centre project. The company also concluded that its newly acquired BIM capability gave it an advantage over others in designing the complex curved girders, and contributed to winning the contract. The ‘Shelter’ project, a public air-raid shelter in southern Israel, was the second project designed by Star, which made use of BIM. The data below shows the reductions in costs, etc, pertaining to these projects. And from the study one can infer the impact of formal advanced training on BIM operators’ productivity.

Project		Blackfoot Crossing (KD&A)	Eagle Ridge (KD&A)	Modi’in Star	
				Level 3.50	Level 0.00
Project Type		Architectural Precast Facade	Total Precast Structure	Pre-stressed Concrete Girders	
Concrete quantity (m ³)		71.6	3,700	82	49
Number of general arrangement drawings		21	25	42	36
Number of shop drawings		63	522	30	33
BIM working hours		489	2,854	124	95
Estimated CAD working hours		502	3,583	171	181
Productivity (hours/ m ³)	BIM	6.8	0.8	1.51	1.94
	CAD	7.0	1.0	2.09	3.68
	Reduction (%)	2.6%	20.3%	27.8%	47.4%
Productivity (hours/ drawing)	BIM	7.8	5.5	4.12	3.17
	CAD	8.0	6.9	5.70	6.02
	Reduction (%)	2.6%	20.3%	27.7%	47.3%

Table 2: Cost savings from BIM-driven precast concrete design project [Source: Israel Kaner - Ref: 3]

2.4 The Camino Medical Group project in Mountain View, California

This case study [Ref: 4] presents the use of BIM tools and processes for the coordination of MEP systems on a \$96.9M healthcare project in Northern California. It is a new 250,000 square foot Office Building for the Camino Medical Group. The construction started in January 2005 and was completed in April 2007. The group has quantified specific benefits from the use of BIM tools and processes that each team member recognized by implementing them for the coordination of MEP systems. Some of these include labour savings ranging from 20 to 30 % for MEP subcontractors, 100% pre-fabrication for

the plumbing contractor, less than 0.2% rework for the whole project for the mechanical subcontractor, zero conflicts in the field installation of the systems and a drastically reduced number of requests for information for MEP systems coordination between contractors and the designers, as well as 6 months' savings on the schedule and \$9M savings in cost for the overall project (see Table 3 and Figure 3 below).

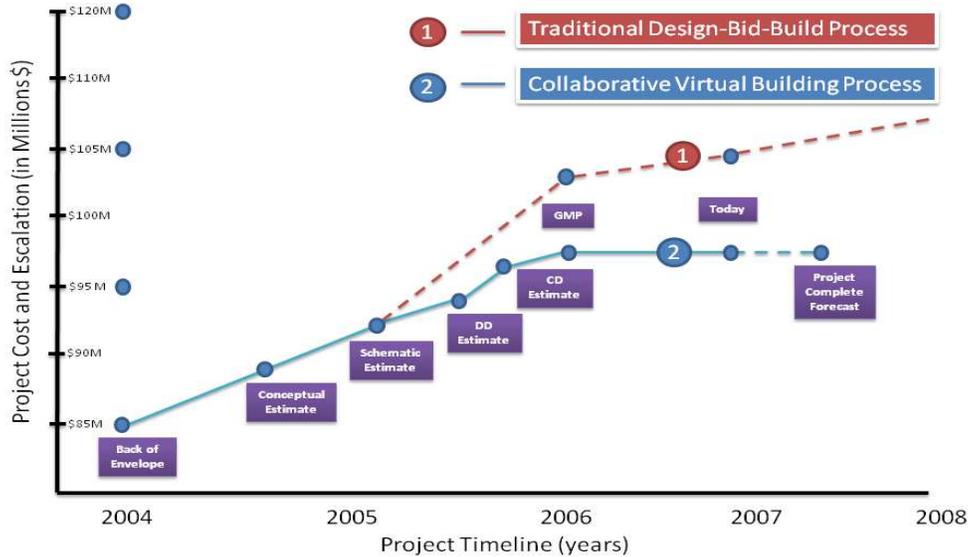


Figure 3: Project cost vs. Timeline [Adapted from: Atul Khanzode - Ref: 4]

Description	ROM Value	Specialty
Separate standby and emergency power based upon early review with authorities having jurisdiction	\$ 15, 000	Electrical
Design assist security	\$ 20, 000	Electrical
Parking garage circuit routing coordination with Ralph	\$ 5, 000	Electrical
Deep underground conduit coordination with footings	\$ 20, 000	Electrical
Early city of Mountain View meeting to reduce fire alarm and exist signage requirements	\$ 30, 000	Electrical
MOB overhead coordination in 3D in conjunction with prefab.	\$ 450, 000	Electrical
Cable tray VE	\$ 200 000	Electrical
Pre-fabrication to eliminate safety issues	\$ 500, 000	Electrical
Working TEE feeder schedule	\$ 10, 000	Electrical
Continual assessment of design and budget	\$ 300, 000	Electrical
Review of parking garage fixture selections and recommendations to stay within budget	\$ 30, 000	Electrical
Vendor commitments/pricing locks	\$ 225, 000	Electrical
Commodity procurement escalation avoidance	\$50, 000	Electrical
Verticality of plumbing system suggested by JWM. Savings due to minimizing the coordination issues with other trades and due to savings in installation labor	\$ 1, 690, 000	plumbing
JWM assisting in equipment selection resulted in savings	\$ 100, 000	plumbing
Early underground piping coordination to miss all deep grade beams in the MOB	\$ 52, 500	plumbing

JWM suggestion to go with normal facets on most faucets instead of sensor faucets which equally have been recommended for only 35 faucet locations	\$ 300, 000	plumbing
Total	\$ 5, 356, 980	

Table 3: Breakdown of savings due to BIM usage in electrical and plumbing [Source: Atul Khanzode - Ref: 4]

2.5 Becerik-Gerber and Rice Survey

Becerik-Gerber and Rice [ref: 5] made an elaborate survey to assess the many characteristics of BIM usage to gauge the benefits. Around 41% of the respondents realized an increase in overall project profitability with its use, while 12% of the respondents reported that there was actually a decrease. Firms having more experience in implementing BIM, seemed to indicate a higher return.

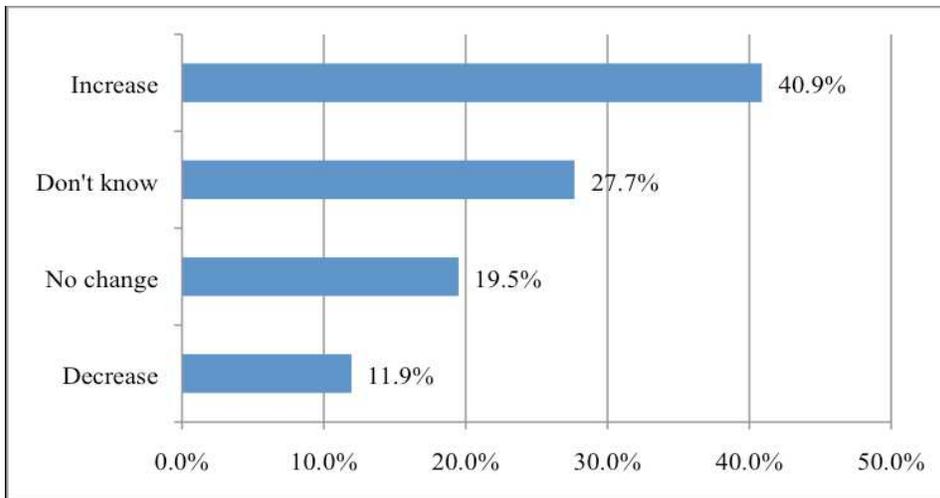


Figure 4: BIM vs. project profitability [Source: Burcin Becerik-Gerber - Ref: 5]

The reduction of both project duration and associated savings contributes in some aspects of project profitability. A majority of the respondents (55%) said BIM helped cut project costs, with 50% indicating project costs were reduced by up to 50%. Fifty-eight percent of the surveyed professionals found that overall project duration was reduced by as much as 50%.

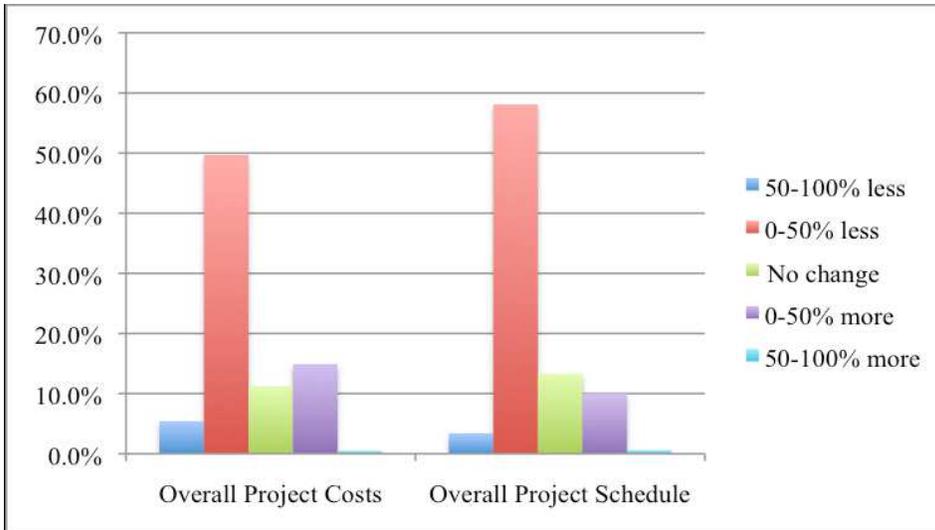


Figure 5: BIM vs. project costs/schedule [Source: Burcin Becerik-Gerber - Ref: 5]

When the project phase durations were analyzed, the schematic and conceptual design phases were seen to take slightly longer when BIM was used, while the duration of the detailed design phase is reduced. Overall, 48% of the respondents think that the detailed design phase takes less time with BIM, while 31% think this phase takes more time. Almost all respondents agree that the construction drawings phase is almost non-existent when using BIM. The quality of the documents produced also improved substantially with BIM. While 44% of the respondents think that there is no change to bid preparation time with BIM, 47% think that the bid preparation phase takes less time, and 9% think this phase takes more time. Though there is a reduction of durations in almost all stages, the most significant one is in the actual construction phase, with approximately 58% of respondents reporting a reduction, while 6.8% think this phase actually takes more time.

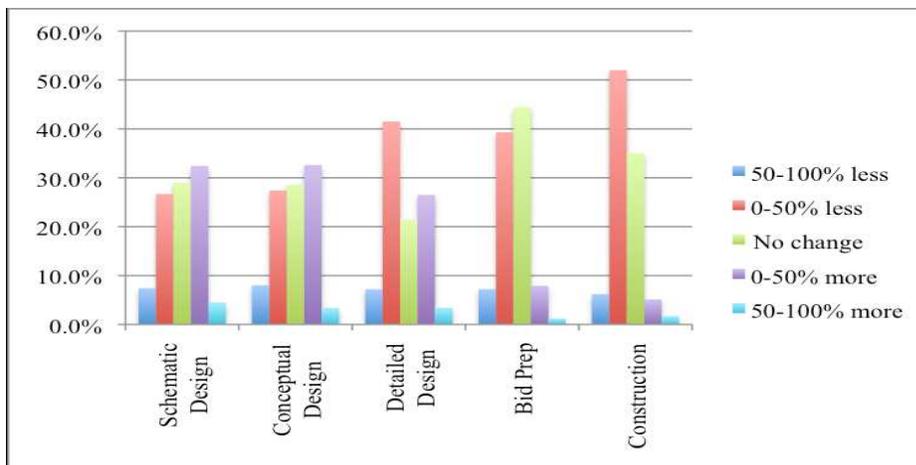


Figure 6: Variations in task durations with BIM [Source: Burcin Becerik-Gerber - Ref: 5]

The survey also examined the ratio of dollar amounts of approved change orders, claims and disputes, as well as correcting errors and omissions to overall project costs. Overwhelmingly, each of these expenses cost less than 0.5% of the total project cost, as per the respondents.

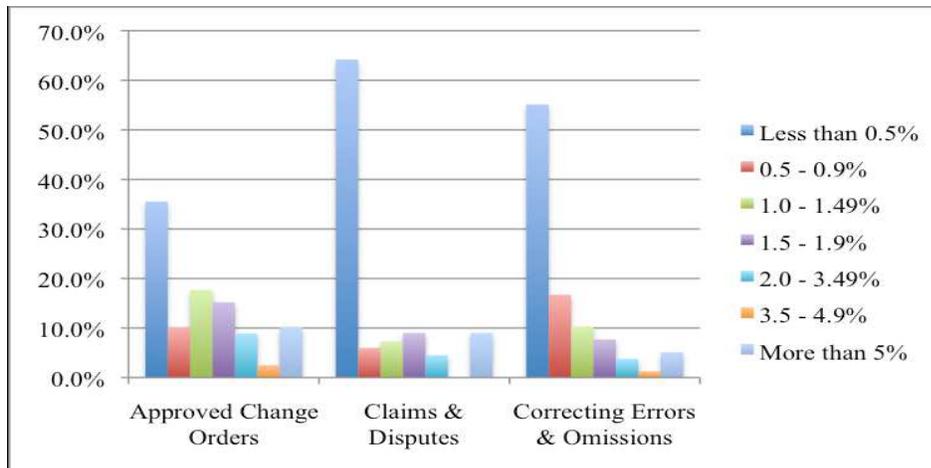


Figure 7: BIM's influence on change orders, claims and disputes [Source: Burcin Becerik-Gerber - Ref: 5]

2.6 Kristen Barlish Study

Kristen Barlish [Ref: 6] conducted an elaborate case study to measure the benefits of BIM as part of a master's thesis in Arizona University. The study elaborates detail findings from 'Company 1' - the company name is kept confidential. Three BIM cases related to Company 1 are studied:

- Case 1 – focusing returns
- Case 2 – focusing investments
- Case 3 – focusing returns and investments of a particular functional area

Each case study was carried out with the intent to present a valid comparison of 2D versus 3D project metrics. Case 1 is based on two 2D historical projects and two 3D pilot projects in similar functional areas. Case 2 is based on a more recent project that is utilizing both 2D and 3D in the same three functional areas. Case 3 is a study on one particular functional area, based on two historical 2D projects, two historical 3D projects, and a more recent 2D and 3D project. The data were compared as total 2D vs. total 3D metrics for a specific case's functional areas. The most quantifiable returns focused on: schedule, change orders, and RFIs. Values were reported with respect to 2D projects, 3D projects, and percent change or differential in units of quantity per assembly, cost of change per cost of total project, and actual versus standard duration.

Case 1: Returns

As mentioned, Case 1 served as a historical account of the returns experienced from BIM's utilization in Company 1. As the Table below depicts, the data shows a positive differential or a net gain from 3D projects.

Case 1 Return from 2D to 3D

Metric	Unit	2D	3D	Δ (2D vs. 3D)
RFIs	Quantity/tool	6	3	3
Change Orders	% of standard project costs	12%	7%	42%
Schedule	% behind standard schedule	15%	5%	67%

Case 2: Design and Construction Investments

This case was established to illustrate the investments or cost of 3D on a more recent project. The data clearly shows that costs are incurred due to 3D design and a saving is experienced due to 3D construction. The RFP for Case 2 required that the electrical, mechanical, and process piping contractors submit their bids in two different formats.

Case 2: Investments from 2D to 3D

Metric	Unit	Differential (2D vs. 3D)
Design Costs		
A&E Costs	% of total awarded design scope	31%
3D Background Model Creator Costs	% of total awarded design scope	34%
Construction Costs		
Contractor Costs	% total awarded construction scope	(-5%) (savings)
Design + Construction Costs		
Overall Savings with 3D in Design and Construction	% total awarded design and construction scope	(-2%) (savings)

Case 3: An Area's Returns and Investments

As a check to provide another data set, a specific functional area was chosen and the returns and investments were analyzed. The results (below) show a change order savings as a much higher percentage than Case 1, which contains this functional area as well as two others. The percentage suggests that this area is receiving the highest returns from change orders.

Case 3: Returns from 2D to 3D

Metric	Unit	2D	3D	Δ (2D vs. 3D)
RFIs	Quantity/tool	2	3	-1
Change Orders	% of standard project costs	23%	7%	70%
Schedule	% behind standard schedule	15%	7%	53%

Upon further observation, using the same metrics as Case 2, the returns of Case 3 are calculated as shown below. The design costs are slightly higher than would be applicable to the specific functional area, and the contractor savings are higher than for Case 2.

Case 3: Investments from 2D to 3D

Metric	Unit	Differential (2D vs. 3D)
Design Costs		
A&E Costs	% of total awarded design scope	29%
3D Background Model Creator Costs	% of total awarded design scope	47%
Construction Costs		
Contractor Costs	% of total awarded construction scope	(-6%) savings
Design + Construction Costs		
Overall Savings with 3D in Design and Construction	% of total awarded design and construction scope	(-1%) savings

2.7 Patrick C. Suermann et al Survey

Patrick C. Suermann et al. Survey [Ref: 7] conducted an elaborate survey centered on BIM's impact with respect to six key performance indicators (KPIs) often used in the construction industry as accepted metrics for assessing job performance. These are: quality control (rework), on-time completion, cost, safety (lost man-hours), dollars/unit (square feet) performed, and units (square feet) per man hour. The results based on 50 respondents showed the following rankings in terms of benefits experienced by the users: Quality Control/Rework (90%), On-time Completion (90%), Cost-Overall (84%), Units/Man hour (76%), Dollars/Unit (70%), and Safety (46%). The information is read as, for example, BIM improved quality Control/Rework KPI for a total rating of 90%.

2.8 B Giel et al Case Study

B Giel et al. [Ref: 8] have presented two case studies on two sets of similar projects -- one a recently constructed BIM-based project and the other an earlier compatible project but without the use of BIM. The potential savings to an owner choosing to invest in BIM were estimated based on the measureable cost benefits associated with reduced schedule overruns and reduced change order costs.

Case Study 1:

Two similar projects constructed by Company X were compared. Project A was constructed prior to Company X's use of BIM, while project B was completed at a later date while using BIM. Projects A and B are comparable in terms of size, scope, contract value, delivery method and construction type. The estimated ROI of BIM that could have been realized by the owner on Project A was determined based on an analysis of what BIM preventable conflicts occurred and their associated direct and indirect costs. And the ROI of BIM on project A would have been 36.7%. Please see the tables below.

Project A and B Results		
	Project A (Pre-BIM)	Project B (BIM-Assisted)
Contract Value:	\$7,128,000.00	\$8,844,073.00
Cost of Change	\$376,837.67	\$271,851.83
Orders:		
Schedule Duration:	12 months	12 months
Schedule Delay:	7 days	0 days
Delivery Method:	Negotiated Bid	Negotiated Bid
Contract Type:	GMP	GMP
Square Footage:	123,000 SF	(3) 81,000 SF bldgs.
Use:	Com. warehouse w. leasable mixed-use space	Com. warehouse w. leasable office space
Construction Type:	Tilt-up wall with steel framing	Tilt-up wall with steel framing
Scope:	CM - all concrete-work self performed	CM - all concrete-work self performed

Table 4: Cost comparisons with and without BIM usage in case study1 [Source: B Giel et al - Ref: 8]

Project A: BIM ROI	
Cost Category	Amount
Total direct cost of subcontracting out panel shop drawings:	\$16,650
Direct costs in preventable change orders:	
Embed fix change order:	\$928
Girder and joist seat fix change order:	\$8,499
Girder and door opening conflict change order:	\$5,664
Total:	\$15,091
Indirect costs of 7-dayBIM-preventable time overrun:	
Daily cost of contractor time overrun (General Conditions) (\$855/day):	\$5,985
Daily cost of 5% interest on construction loan for time overrun (\$976/day):	\$6,832
Daily cost of developer administration for time overrun (\$446/day):	\$3,122
Estimated cost of architect's contract administration for time overrun (\$149/day):	\$1,043
Total:	\$16,982
Total Estimated Savings:	\$48,723
Cost of BIM (0.5% of contract value)	\$35,640
Net BIM savings:	\$13,083
ROI:	36.7%

*Note: The cost of investment was approximated at 0.5%, as furnished by the owner for BIM services in th contract. A 5% CAP rate was assumed on the Owner's construction loan for the purpose of this study.

Project B: BIM ROI from Indirect Savings	
Cost Category	Amount
Total direct cost of subcontracting out panel shop drawings: (\$0.13/SF X 243,000 SF)	\$31,590
Indirect costs of 7-day BIM-prevented time overrun:	
Daily cost of contractor time overrun (General Conditions) (\$888/day):	\$6,216
Daily cost of 5% interest on construction loan for time overrun (\$1212/day):	\$8,484
Daily cost of developer administration for time overrun (\$544/day):	\$3,808
Daily cost to architect's contract administration for time overrun (\$181/day):	\$1,267
Total:	\$19,775
Total Estimated Savings:	\$51,365
Cost of BIM (0.5% of contract value)	\$44,220
Net BIM Savings:	\$7,145
ROI:	16.2%

Table 5: BIM-enabled savings comparisons for two projects in case study1 [Source: B Giel et al - Ref: 8]

Case Study 2:

The methodology used in Case study 1 was also used in Case study 2 also projects C and D; projects C and D are comparable. Please see the table below. Also, note here that in addition to project C's associated multiple BIM preventable direct cost, its schedule was delayed by a total of 426 days past its original 601 day duration. The data also revealed that project C's predicted BIM ROI would have been around 1654%, and project D's ROI was estimated at roughly 300%.

Project C And D Results		
	Project C (Pre-BIM)	Project D (BIM-Assisted)
Contract Value:	\$41,757,618.00	\$44,400,000.00
Cost Of Change Orders:	\$5,097,222.00	\$513,632.00
Original Schedule Duration:	601 Days	652 Days
Schedule Delay:	426 Days	0 (60 Days Early)
Contract Type:	GMP	GMP
Delivery Method:	Negotiated Bid	Negotiated Bid
Square Footage:	439,760 SF	456,594 SF
Use:	Mixed use- res. condo/ garage	Mixed use- res. condo/garage
Number of Stories (Towers):	14 Stories	7 Stories
Number of Units:	311	218
Type of Construction (Towers):	Conv. formwork w. Conv. Reinf.	Conv. formwork w. cast in place tables
Type of Construction (Garage):	Post- tens. conc. w. conc. cols.	(DB) post tens. conc. w. steel cols.
Scope:	CM - all conc. self- performed	CM - all conc. self- performed

Table 6: Cost comparisons with and without BIM usage in case study2 [Source: B Giel et al - Ref: 8]

Cost Category	Amount
Direct costs in preventable change orders:	
(COR 00004) Revised boundary survey:	\$24,862
(COR 00013) Added beam in shear wall:	\$787
(COR 00014) Shear wall # 1 revision:	\$3,396
(COR 00015) Movement of (2) columns due to grid mis-alignment:	\$419
(COR 00025) Addition of (16) 3" deck drains:	\$19,158
(COR 00095) Readjustment of fire sprinkler heads for ceiling height changes:	\$1,777
(COR 00092) Window reorder/install due to conflict with exterior columns:	\$2,632
(COR 00104) Sliding glass doors mislabelled as window type:	\$2,208
(COR 00146) Revised ceiling heights to conceal drop panels:	\$13,062
(COR 00151) Additional framing of roof drains:	\$19,081
(COR 00178) Re-routing of mechanical ductwork around electrical panels:	\$2,722
(COR 00213) Additional soffits to accommodate return air ductwork:	\$14,115
(COR 00231) Additional fire sprinkler heads adjustment for dropped ceiling:	\$1,285
(COR 00175) Demolition and repair of elevator door beams:	\$66,812
(CO 17) Materials escalation due to 221-day delay based on survey and structural plan errors:	\$300,000
Total:	\$472,316
Indirect costs for 221-day BIM-preventable time overrun:	
Daily cost of contractor time overrun (General Conditions) (\$5,425/day):	\$1,198,925
Daily cost of 5% interest on construction loan for time overrun (\$5720/day):	\$1,264,120
Daily cost of developer administration for time overrun (\$2466/day):	\$544,986
Daily cost to architect's contract administration for time overrun (\$822/day):	\$181,662
Total:	\$3,189,693
Total Estimated Savings:	\$3,662,009
Cost of BIM (0.5% of contract value)	\$208,788
Net BIM Savings:	\$3,453,221
ROI:	1653.9%
Project D: BIM ROI of Indirect Time Savings	
Cost Category	Amount
Indirect costs saved by 60-day early completion:	
Daily cost of contractor (General Conditions) (\$5,425/day):	\$325,500
Daily cost saved in interest (5%) on construction loan (\$6,082/day) :	\$364,920
Daily cost of developer administration (\$2,466/day):	\$147,960
Daily cost to architect's contract administration for time overrun (\$822/day):	\$49,320
Total:	\$887,700
Total Estimated Savings:	\$887,700
Cost of BIM (0.5% of contract value)	\$222,000
Net BIM Savings:	\$665,700
ROI:	299.9%

Table 7: BIM-enabled savings comparisons for two projects in case study2 [Source: B Giel et al - Ref: 8]

2.9 Data Compiled by Salman Azhar et al

Salman Azhar et al. [Ref: 9] have compiled the data of ten US projects (see below) based on BIM Economics, to illustrate the net BIM savings and BIM's return on investment (ROI). From the data it is noted that the ROI for different projects varied from 140% to a whopping 39900%.

Year	Cost (\$M)	Project	BIM Cost (\$)	Direct BIM Savings (\$)	Net BIM Savings	BIM ROI (%)
2005	30	Ashley Overlook	5,000	(135,000)	(130,000)	2600
2006	54	Progressive Data Center	120,000	(395,000)	(168,000)	140
2006	47	Raleigh Marriott	4,288	(500,000)	(495,712)	11560
2006	16	GSU Library	10,000	(74,120)	(64,120)	640
2006	88	Mansion on Peachtree	1,440	(15,000)	(13,500)	940
2007	47	Aquarium Hilton	90,000	(800,000)	(710,000)	780
2007	58	1515 Wynkoop	3,800	(200,000)	(196,200)	5160
2007	82	HP Data Center	20,000	(67,500)	(47,500)	240
2007	14	Savannah State	5,000	(2,000,000)	(1,995,000)	39900

2007	32	NAU Sciences Lab	1,000	(330,000)	(329,000)	32900
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Table 8: BIM-enabled savings comparisons of multiple projects [Source: adapted from Salman Azhar - Ref: 9]

2.10 Lott + Barber Architects Study

Lott + Barber Architects [Ref: 11], an architectural and planning firm based in Georgia, began to use BIM in 2004. To measure its productivity gains, the company compared the time spent on different stages of the design process of two projects of similar size and scope, using BIM vs. traditional CAD tools. As seen from the table below, it has experienced gains across all major segments of the design process and in its construction documentation process.

Task	CAD (hours)	BIM (hours)	Hours saved	Time savings
Schematic design	190	90	100	53%
Design development	436	220	216	50%
Construction documents	1023	815	208	20%
Checking and coordination	175	16	159	91%
Totals	1824	1141	683	

Table 9: Traditional CAD vs. BIM-driven design time comparisons [Source: Cadalyst web page - Ref: 11]

2.11 Brittany Giel and Raja Issa Study

Brittany Giel and Raja Issa [Ref: 12] present data gathered from 3 case studies based on three sets of two similar projects. Here, the potential savings to an owner choosing to invest in BIM as an additional service were estimated based on the measurable cost benefits associated with reduced schedule overruns and reduced change order costs. The data pertaining to just one of the three case studies is given below.

Project Details	Project 1 (Pre-BIM)	Project 2 (BIM-Assisted)
Contract value	\$10,701,967	\$11,799,071
Original schedule duration	13 months	14.6 months
Schedule delay	2 months	0
Contract type	Design Assist	Design/Build
Delivery method	GMP	Stipulated Sum
Square footage	120,000 SF	66,926 SF
Use	Assisted Living Facility	Assisted Living Facility
Stories	3	3
Units	131	80

Table 10: Pre-BIM and BIM assisted projects comparison [Source: B Giel et al - Ref: 12]

There were 4 specific change orders associated with Project 1, which could have been prevented if BIM had been utilized. Inaccuracies in the construction drawings necessitated modifications to the balconies of two unit types. Another change order resulted from a clash between the roof scuppers and exterior walls. Other inconsistencies in the construction drawings caused several doors to be resized. In addition, inspection also revealed that two 4-hour, fire-rated walls were missing and Project 1's completion was delayed two months. The resulting change order included the cost of the demolition of the existing walls and ceilings plus the material and labor costs for correction. These issues would likely have been uncovered if BIM had been used. As shown below, the estimated ROI of using BIM on Project 1 may have totalled 376 percent if the technology had been implemented.

Project 1 BIM: Projected ROI	
Cost Category	Amount
Direct costs in preventable change orders:	
Unit 227 and 228 shell overages	\$6,202
Roof scupper re-route	\$6,515
Door re-size at closets/mech. room	\$833
4-hour wall rework and construction	\$17,225
Total	\$30,775
Indirect costs of 60-day BIM-preventable time overrun:	
Daily cost of contractor time overrun (general conditions) (\$1410/day)	\$84,600
Daily cost of 5 percent interest on construction loan for time overrun (\$1466/day)	\$87,960
Daily cost of developer administration for time overrun (\$641/day)	\$38,460
Estimated cost of architect's contract administration for time overrun (\$214/day)	\$12,840
Total	\$223,860
Total estimated savings	\$254,635
Cost of BIM (0.5 percent of contract value)	\$53,510
Net BIM savings	\$201,125
ROI	376 %

Table 11: Potential savings if BIM were used in the Pre-BIM project [Source: B Giel et al - Ref: 12]

The ROI of using BIM on Project 2 was estimated based on the number of clashes that were uncovered using BIM during preconstruction. Many conflicts were resolved, most of which were the result of discrepancies between the shaft detail drawings and the interior dimensions. It should be noted that if traditional methods were used, these discrepancies would not have been uncovered until at least a month into the project schedule. There were also many conflicts between the ceiling heights of several units and the structural disciplines that were revealed during preconstruction using BIM. Through analysis of these major conflicts, it was projected that the use of BIM for coordination saved at least one month of schedule overrun time on Project 2.

Project 2 BIM ROI	
Cost Category	Amount
Indirect costs of 30-day BIM-prevented time overrun:	
Daily cost of contractor time overrun (general conditions) (\$1554/day)	\$46,620
Daily cost of 5 percent interest on construction loan for time overrun (\$1616/day)	\$48,480
Daily cost of developer administration for time overrun (\$706/day)	\$21,180
Estimated cost of architect's contract administration for time overrun (\$235/day):	\$7,050
Total estimated savings	\$123,330
Cost of BIM (0.5 percent of contract value)	\$58,995
Net BIM savings	\$64,335
ROI	109 %

Table 12: Detail savings associated with the BIM–assisted project [Source: B Giel et al - Ref: 12]

2.12 Russell Manning and John Messner Study

Russell Manning and John Messner [Ref: 13] presented two case studies based on data gathered from health care facilities. The first was a new hospital in the Middle East of 8,920 square meters; and the second is a renovation of an occupied medical research facility of 6,220 square meters in the United States. The data collected focuses on how the owner utilized BIM tools to help their internal project development during the planning and programming stages.

In the first case, the hospital project had originally been programmed as a modular and fixed facility solution, and functionally and operationally designed as a standard North American regional medical center. The project had gone through conceptual development, programming, approval, and contracting, which took approximately 29 months. Associated 2D plan drawings, completed by a CAD architect, took over 350 hours of work spread over approximately 24 months. But the whole plan was cancelled for multiple reasons that are not elaborated here. A decision was made by the owner to redesign the first attempt to better match the functional and operational realities of the region and to go with a totally modular facility concept. The re-design using BIM took approximately 214 hours of design time over 44 days. There were other qualitative benefits as well, again not listed here.

The second case study project, the Medical Research Lab, was the renovation of an existing building. The team decided to implement the use of BIM to help with basic project planning. It is noted that, historically, the owner would lose one to two weeks of site investigation time once the Architectural and Engineering (AE) was on board trying to establish accurate space utilization that all user divisions could agree upon. And based on past projects, it was estimated that this saved approximately 100+ person-hours of time previously expended through the contracted AE. The modeling effort took 78.5 man-hours including all revisions, yielding approximately 20% savings in person-hours for the existing division and department space calculations – this is equivalent to an approximate cost savings of 62%. As in the previous case, there were other benefits also.

2.13 Stefan Dehlin and Thomas Olofsson Study

Stefan Dehlin and Thomas Olofsson [Ref: 14] have developed a project-oriented evaluation model to provide for a structure to be used by a multidisciplinary project team to evaluate the implications of realizing ICT investments in construction projects. Though BIM was not used explicitly, its effectiveness is measured using a virtual reality (VR) based construction case study. And as per the study, the company involved found improvement in several areas such as those listed below.

Operating cost reduction	Contribution to achieving goals
Staff reductions	Service effectiveness
Overall productivity gains	Time effectiveness
Increased work volume	Improved information management
Product quality	Increased profits

Quantitative data shows the following benefits:

Benefit	Quantification
Staff reduction	EUR 1 280 K
Clashes (reduction)	EUR 1 200 K
Earlier completion of project due to better coordinated shop drawings	EUR 6 000 K
Project Coordination	EUR 2 000 K
Better information quality	EUR 50 K
Better insight into various aspects of the project	EUR 100 K

Table 13: Savings breakdown in a BIM-enabled project [Source: Stefan Dehlin - Ref: 14]

3. The ROI Indicators in Construction – the Metrics

There has been a lack of consistent benchmarking measures regarding investment and returns when moving from a traditional CAD to BIM technology. Putting things further into perspective, IT investments are often characterized as being hard to evaluate due to difficulties in quantifying the relevant costs and benefits and due to the high degree of uncertainty with respect to a value proposition. Often the benefits from IT investments fall into an intangible and qualitative category (e.g. improved quality, ability to make better decisions, availability of seamless data, etc.). The process and cost incurred in implementing BIM software and associated processes are not trivial; the adoption of BIM requires real changes in thinking and in the way industry has been designing and building. In addition, in almost all cases managers need to prove that the investment in BIM technology will produce a tangible return even before the money has been budgeted.

Typically, the rationale for the ROI in a BIM-based construction project is based on several factors enabling the organization to:

- Reach a good understanding of the impact of a BIM investment on organizational performance
- Plan for, monitor and accomplish benefit realization and identify any future benefits
- Handle and mitigate risk and costs associated with benefit realization
- Gather data for benchmarking that can be used to provide a measure of the actual implementation for other IT-based investment

With these in mind, and examining the various case studies described in this document, it is becoming very obvious that there is no consistency in the metrics that have been used in measuring the ROI in construction. Typically, construction industry clients want their projects delivered on time, on budget, right first time, free from defects, efficiently and safely; they also expect continuous improvement from their team which should enable them to achieve further reductions of project costs and project durations. In this scenario, to arrive at a consensus on ROI metrics will enable the measurement of organizational performance, thereby achieving a uniform understanding on the benefit of embracing the BIM process. The performance metrics can then be used for benchmarking purposes of any IT related technology introduction and will also become an important component of a company's effort towards achieving better productivity.

It should be emphasized here that the broad notion of construction benchmark indicators, often talked about as key performance indicators (KPI), may not have a one to one mapping with respect to the performance metrics noted in the paragraph above, in the sense that such KPIs are used to compare the performance of one particular company against others, based on the industry norm (or averages). Its purpose is to identify gaps based on the KPIs and actual company performance, which then can become the point of focus, whereby actions are triggered to address the gaps. On the other hand, the performance indicators inferred from each specific case study reported in this report are for project instances based within the same company - a project that makes use of BIM, and an equivalent one that doesn't. A net gain based on the summation of the numbers representing these performance indicators can easily justify BIM's investment reasoning in terms of cost. In addition, the case study data given in this report depicts yet only a snapshot of the return (i.e. static data), whereas with BIM the benefits are expected to continue throughout the continuation of a project's life cycle phases, which include operations and maintenance.

To formalize the ROI performance metrics applicable to BIM and/or other IT-based technology investment, it is important to understand the organizational inputs, outputs, and desired outcomes; these metrics should be as closely linked to the top-level goals of the organization. Answers to the following may be sought for clarification of such indicators:

Is the performance indicator measurable?

Is the performance indicator even meaningful?

Is the measurement of the performance indicator cost-effective?

Has the organization any control over the factors affecting the performance indicator?

Based on such questions and, as detailed in Coates et al. [Ref: 15] one may arrive at a number of performance factors like:

- Person hours spent per project: compare the person-hours spent on one project that utilises BIM with the person-hours spent on the same project that would use a traditional CAD system.
- Speed of development: turnaround time is important as it can reduce the work and costs, and improve cash flow; the speed of turnaround also contributes to client satisfaction.
- Revenue per head: for many clients, the value of BIM remains unproven in many areas including facilities operations. Clients will pay a higher cost if they perceive greater value.
- IT investment per unit of revenue: it is the norm in architectural practice to use IT; many solutions may be possible, but one has to measure the merits of one against the others.
- Cash flow: good cash flow allows for meeting the company's obligations. By increasing the speed at which product is turned around means invoices can be issued earlier.
- Better product: ultimately, BIM produces a better product through reduction of mistakes, detection/elimination of clashes, automated model checking, and reduction in build-ability issues, etc.
- Reduced costs associated with travel, printing and shipping: as the number of issues is reduced, travel and need for shipping are reduced; printing costs are saved because drawings incur less checking.
- Bids won or win percentage: BIM can be considered a marketable commodity, and with its modelling and visualization capability may help to attain a competitive advantage to win bids.
- Client satisfaction: capturing client requirements and establishing shared understandings are vital; BIM makes client interaction and feedback easier which can also result in better client satisfaction.

In sync with the above factors, a UK based working group [Ref: 16] on performance indicators has come up with a framework that consists of seven main groups, namely: Time, Cost, Quality, Client Changes, Client Satisfaction, Business Performance and Health & Safety. Some of these parameters are qualitative in nature; for example, client satisfaction is somewhat difficult to use as a quantifiable measure. Certain other items can be reformed to make it almost quantitative: for example, quality (perhaps, the lack of it) can be measured by means of the amount of rework done; safety can be

measured by means of the lost person-hours. With the same mindset as the UK based working group above, Patrick Suermann [Ref: 7] has established 6 quantifiable performance indicators, which are:

- Quality Control (rework reduction)
- On-time Completion (reduction in delay)
- Cost-Overall (cost reduction)
- Units (square feet)/person hour
- Dollars/Unit (square feet), and,
- Safety (reduction in lost person-hours)

The performance indicators noted just above, though only six in number, seem to include dominant parameters related to investment decisions in regard to BIM; accordingly, these six measures could be used as benchmark parameters by construction practitioners. It is interesting to note that only a subset of the above measures was considered in the real-life cases elaborated and studied in this report; yet they are inclusive of the 6 quantitative measures noted above. For instance, interference checking and clash/collision detection via visualization can prevent the need for rework by eliminating such occurrences ahead of time, thereby improving quality. It can reduce labour hours, which in turn reduces the overall costs. Similarly, a reduction in schedule time, as well as reductions in the RFI and change orders can also be equated to a reduction in the overall cost. Yet another cost factor is the number of hours required for documents' creation in a traditional CAD vs. BIM-driven project.

4. Conclusion

Notable points that can be summarised from this report are:

- Data, based on real-life construction projects and associated case studies, indicates that investment in BIM is worthwhile and almost always, gives a positive return.
- In regard to BIM technology implementation, the notion of ROI is based on investments in software, hardware, procedures, training and data.
- Case studies depicted in the report provide a snapshot of the benefits, tagged to a single project (i.e. the current) only; benefits and values attainable in potential future projects, as a result of the knowledge gained in using BIM, will be in addition to the dollar amount noted in the cases.
- Since most BIM-driven projects are recent undertakings, the benefits attributable to a project's total lifecycle (and hence BIM's long term impacts) cannot be quantified at present; also, it may be premature to expect such data to become available in the near future.
- There is no universal or consistent metric that was used to measure the returns in any of the cases involving the construction projects.
- The six (6) metrics discussed in the previous section can be used as tangible measures for the ROI in regard to BIM; it can be used by most companies wanting to embrace the technology.

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