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An Evaluation of the Impact of Integration and Computerization on Construction Projects

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Abstract

The level of awareness and actual implementation of integration and computerization in the construction industry is growing. However, it is not clear at this point how to assess the extent of their impact and to identify in which ways they better support the construction projects related to their success. The objectives of this research are the development of a model to evaluate the impact of integration and computerization on construction projects and the recommendation of guidelines for companies in identifying suitable ways for them to incorporate integration and computerization into their operation. The developed conceptual model has been found robust enough to be used as a benchmarking tool in evaluating the performance of the construction process and to strategize its future operation.

Keywords : Integration, Computerization, Project Success, Evaluation Model, Benchmarking

1. Introduction

The level of awareness and actual implementation of integration and in the construction industry is growing. With the recent information technology development integration is now more spotlighted as known to provide cost effectiveness and also improves the quality of the product. However, it is yet clear how and to what extent integration has an impact on the construction projects.

1. Evaluation Model

It is often asserted that integration provides savings on time and money resulting in cost effectiveness and it also improves the quality of the product. This research attempted to investigate the validity of its claim. To do that, a conceptual model is introduced. This conceptual model is intended not only as a useful tool to quantify the claims, but also as a guide to assess the strategy impact of integration. The strength of the model is its foundation on the model and techniques (Design Effectiveness[2]) that is popular and accepted by top management of corporations. The model also provides a means of evaluating various kinds of the projects. Finally it can be used for identifying components of integration on the basis the applications and operations of the surveyed project.

For this model, two dimensions are initially introduced. One is integration and the other is project success. The horizontal axis measures the level of integration and the vertical axis measures the level of computerization. The higher the level, the farther it goes from the original point. The extreme values (lowest and highest) for both variables define a rectangle. The rectangle is segmented into four areas which represent four major groups of projects with regard to the level of integration and computerization. These four areas are representing low-low, low-high, high-low, and high-high combination of integration and computerization. Projects are characterized this way. For example, project A is characterized by the use of low integration and low computerization, on the other hand, project B is utilizing the combination of high integration and high computerization(Figure 1). This chart allow us to compare the level of integration and computer technology used in one project with another.

After the level of integration and computerization in a given project are observed, measured and quantified, it is plotted in the defined

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2. Scarlett, B. R., and Tucker, R. L., Evaluation of Design Effectiveness, A Report to The Construction Industry Institute, 1986.

region. The project success as the third dimension is delivered in order to measure the benefits of given combination use of the other two.

The level of success will appear as the height of the previously positioned project on the plane because the third dimension is introduced. The following figure shows an example of how the chart will turn out after the measurement of three dimension is completed (Figure 1).

The level of integration, computerization and project success can be determined by additive polynomial functions.

The integration function for example is defined as follows (Equation 1):

$$I = a_1x_1 + a_2x_2 + a_3x_3 + ... + a_nx_n$$

$$I = \sum_{i=1}^{n} a_i x_i \qquad \text{Equation (1)}$$

Where:

I : Observed Level of Integration

a_i : Weight Factor

x_i : Integration Attributes

The level of computerization and project success will use the same equation as above.

2. Integration

The first dimension, integration is discussed here. This section includes the definition of integration, the attributes of integration interpreted as criteria to measure the level of integration.

The term "integration starts with generic definition of integration.

To make a whole or complete by bringing together parts [*Webster Dictionary*].

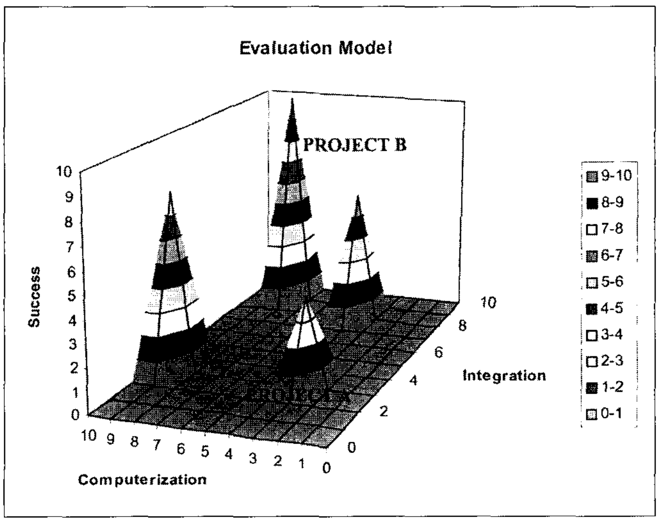

Figure 1: Three Dimensional Evaluation Model

Literally, it implies that parts exist, and a whole will be completed by bringing them together. Integration is not a whole itself. Integration is the process where parts come together to make a whole. According to its definition, the integration model could be the following. The Figure 2 presents integration model. This integration model illustrates the procedure of how integration is accomplished. The procedure of accomplishing integration is presented in order from (a) to (f). Integration is the process from (a) to (f).

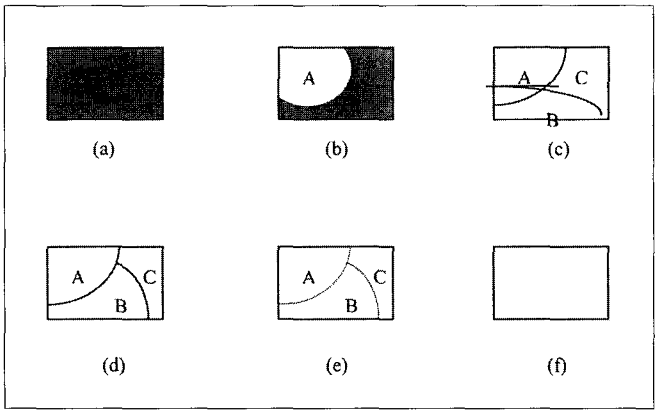

Figure 2: Integration Model

Each rectangle shown represents the aggregation of all tasks required to complete the job. (a) is the state that consists of unallocated tasks. In (b), specialist part A is involved to perform some of the tasks it can do and but still many tasks are remaining unassigned. Other parts which can perform the rest of tasks are required, which means that other parts should be the specialists to take up the rest of the unallocated task. From here, the first attributes of integration is identified. It is complement, which means that each part are linked, more likely geared with respective specialties. In (c), specialists B and C are invited to perform the rest of the tasks so that all the tasks can be performed (no more dark area). At this point, it is assumed that all the tasks can be accomplished. From here, two other attributes of integration is induced. One of them is the competence of the specialists to perform the tasks expected to complete by them. The other attribute is the commitment of the specialists to keep promises with followed actions. In other words, each specialist have ability to do the job and is responsible for the job. Thus, all the required works can be performed by the capable specialist.

However, even though all tasks can be undertaken, the state of (c) is not still desirable, because of duplicated works done by both A and B (the amount of intersection between A and B). This duplication forces specialists to do redundant tasks, which is not effective. Therefore it is necessary to bring another attribute to insure this situation does not occur. Another attribute is coordination which is a arrangement to organize the process and to define scope preventing the specialists from being confused and duplicated jobs. By doing this the state (d) can be arrived at.

State (d) is not still representing a state of a whole because of seams between the parts. The seams are interpreted as the barriers which obstruct the understandings of each other. What can resolve these barriers? One is the exchange of information. Communication defined as "to give or exchange information" introduces another attribute of integration. Communication is very important to minimize the barriers between the parties. The complete and correct information flow from one phase to another makes it possible to transfer the work load smoothly. The accurate information transaction between the specialties improves the understandings among specialists. In other words, communication promotes efficient continuity between phase and concurrence.

Through communication, stage (e) is reached. The act of exchanging information cannot solely remove the barriers. Actually it is impossible to eliminate all the barriers among the specialists because each specialist has its own interest. Each party is characterized as its own identity and has its own goal. However some other attributes may help to lead the specialists closely to the stage (f) which is representing "a whole", the integration.

Therefore some other attributes should be introduced to minimize the barriers possibly resulting in a whole. Those attributes are identified with the help of CII Task Force Study above. One is goal alignment (congruence). Each party should agree on the goals and their efforts should be aligned to accomplish goals. Without agreement, it does not matter how well they communicate or coordinate. The last attribute of integration identified is trust (confidence). This binds teams together tightly and gives reliance on each specialist.

With total seven attributes identified (complement, competence, commitment, coordination, communication, congruence, and confidence), the final stage (f) is reached, a state of whole. Now it is the time to define integration reflected by given attributes. Integration is the process bringing parts together to make a whole. Integration is that each specialist, with the required ability to perform the tasks, works together utilizing coordination and communication, to

Table 1: The Conditions and Indicators of Integration

CONDITIONS	INDICATORS	DESCRIPTION
Complement	Expertise	professions directly related toward specialized work.
	Characteristics	the nature or talent to fully execute certain tasks.
Competence	Experience	the achievement of previous practice and participation.
	Knowledgeable Ability	sufficiency in understanding for required works.
	Technical Ability	sufficiency in practical skills and operations.
Congruence	Project Objectives	awareness and conformity to the project objectives
	Construction Method	consistent operation or procedure to pre-determined methods
	Scope of Work	conformity to specifications and appropriate compliance with changes
	Procurement	agreement in selecting subcontractor, vendors, suppliers, and equipment.
Coordination	Organization Structure	the appropriate arrangement of functional relationships.
	Administration	the management and settlement of official executors.
	Approving Procedure	the effective arrangement of approving and reviewing procedure of drawings and documents.
	Reporting System	the judicious and adequate use of reporting system.
Confidence	Openness	freely communicating ideas and expressing them without fear of repercussion
	Flexibility	flexibility in dealing with particular job circumstance
	Fairness	fair and just treatment of other party in all areas of the project.
Commitment	Involvement	participation in resolving issues, and problem solving.
	Eagerness	an attitude with voluntarily cooperation
	Devotion	concentrated efforts regarding resolving issues and problem solving.
Communication	Clearness	clarity in exchanging information.
	Completeness	completeness of information.
	Correctness	correctness of distributed information.
	Punctuality	availability of information on time

complete the goals they agreed upon, on the basis of trust. To be brief, integration is defined as "Cooperative Teamwork" which addresses joint and coordinated group efforts to accomplish the common goals.

Table 1 represents the attributes of Integration. The seven conditions of integration are looked for in the evaluation of integration. The attributes of integration are composed of with relation to people, management, and technical aspect of a project. Congruence, commitment, and confidence are related to people, coordination is related to management, and competence and complement are related to technical aspect of a project.

3. Computerization

The second dimension, computerization is discussed here. This section includes its definition and list of areas where computer technology are applied and measured. Computerization is defined as "*to use computer to perform or control*". Computer includes hardware, software and other accompanying devices such as printers, plotters, scanners, fax/modem, CD Rom and speakers.

Choi and Ibbs[3] conducted a research to investigate the use of computer in the construction industry. The objective of research was to analyze the current computerization practice in the industry and to predict the future trend. They surveyed 40 companies and collected data based on the use of computer. At that point, 55% of companies involved in the survey were using computer for drafting/design, 50% of them using computer for numerical analysis. The researchers predicted that the use of computer would increase. The areas the research had examined were basically CAD (Computer-aided design) and CAE (Computer aided Engineering). Recently, with the rapid development of computer technology, the use of computer in the construction industry is growing and the areas where the technology is applied are diversified. Therefore a comprehensive list of areas where computer technology can be applied is required in order to properly measure the level of computerization process in the industry.

CIFE have identified four emerging technologies as being able to improve current design and construction process. They are: artificial intelligence, graphic or non graphic database, process automation and robotics, and management and dissemination of technology[4]. These classifications may be not be applicable in this research because they are not yet common in the current industry practice.

3. K. C. Choi, and C. W. Ibbs,. CAD/CAE in Construction: Trends, Problems, and Needs. Journal of Management in Engineering, Vol. 6. No. 4. October, 1990.

Based both on the list of areas from the Choi and Ibb's report and on examining software products[5], the following areas have been selected as the candidate list of measuring computerization in the industry: Budget/Financing, Numerical/Engineering, Drafting/Design, Scheduling/Tracking, Estimating/Accounting, Documenting/Reporting, Data storage, and Communication. More specifically, these broad areas cover functions such as:

4. Project Success

The Second Dimension, project success is based on the results of Ashley's research.

"... results much better than expected or normally observed in terms of cost, schedule, quality, safety, and participant satisfaction." [Ashley, 1987][6]

The criteria of measuring project success are:

- Budget (Cost) : to complete the project on budget.
- Quality (Performance): to meet the performance specifications.
- Schedule: completing the project on time.
- User's Satisfaction:
- Safety

5. Project Survey

The massive survey of the projects by sending questionnaire turned out to a failure because the responses were passive and the results were not quite reliable. Therefore, the selective project survey was adopted by interviewing project participants. Especially evaluating project success had to be performed mainly by the owner of the project so that the evaluation could be trusted.

The selection of the projects was concentrated on the mid-size public or school projects because public or school works are more likely to consistently emphasize the value of project success according to Ashley's five components of project success. Table 2 shows the information of the surveyed projects.

4. H. C. Howard, R. E. Levitt, and B. C. Paulson., Computer Integration: Reducing Fragmentation in AEC industry. Journal of Computing in Civil Engineering, Vol 3, No. 1, 1989.
5. The author attended the AEC EXPO show and conference in New York, 1991.
6. David B. Ashley, Determinants of Construction Project Success, Project Management Journal, Volume XVIII, June 1987.

Table 2: The surveyed Projects

Project	Location	Owner	Architect	G.C.	Budget $Mil
Fuller Lab	Salisbury St. Worcester	Worcester Polytechnic Institute	Payette Associates Inc.	Harvey and Sons Inc.	9
Higgins Renovation	West St. Worcester	Worcester Polytechnic Institute	Cutler Associates.	Cutler Associates	10
Bancroft School	Shore Drive Worcester	Bancroft School	Lamoureux	E. J. Cross	2.9
Site Work of Medical City	Central Blvd. Worcester	Worcester Redevelopment Authotity	Maguire Group Inc.	P. Gioioso and Sons Inc. S&R Contracting Group	11
Remediation of Soil	Central Blvd. Worcester	Worcester Redevelopment Authority	Metcalf & Eddy	Triumvirate Environmental I. E. M.	8
St. Andrew Church	Holden MA	St. Andrew Church	Fitzerard	Harvey and Sons Inc.	6
Oxford Achadeny	Northborough MA	Oxford Academy	Johnsons	Stone & Webster	8
Elementary School	Main St. Worcester	City of Worcester	City of Worcester	Callahan & Sons Inc.	9.5

6. The Results

The results of the survey were analyzed in four ways; 3D evaluation model chart, 2D correlation analysis, Cross Table analysis and Sensitivity analysis. Among them sensitivity analysis was taken mainly for defining the proper weight factors of each attribute. To simplify, the most noticeable results will be presented here.

The scores obtained for the project success, integration, and computerization were summarized. Each score was expressed as a percentage of total possible score. The percentage presented for each variable of each project is the level of each dimension of the evaluation model. The levels of three dimensions were obtained by using the average score of the project team, the owner, architect, and contractor.

Figure 3 helps to visualize the patterns or trends from the project evaluation. This 3D surface chart connects the extreme points of each project.

It is likely to say that once a certain degree of integration was achieved (more than 70%), a project was reasonably successful. However, if a good integration was performed with high computerization, the project success increased (see the marginal leap at the back corner). In other words, computerization by itself, high or low, does not seem to have much to do with project success, but it seems to have competitive advantage when it is used with high integration. The overall trend is that since the highest points are observed in the back corner, more integrated and computerized project tends to be more successful. This may tell us that the construction industry is approaching more integrated and more computerized process.

The 2D analysis examines the correlation between the three main variables; project success, integration, and computerization. Coefficient and significance level are given to measure the correlation.

From the Figure 4, there is a positive correlation between project success and integration. The overall trend is that the more integrated the project, the more successful. Figure 4 shows there is a strong correlation between project success and integration. However, Project Success vs. Computerization and Integration vs. Computerization seem to have no correlation between the two respectively. They

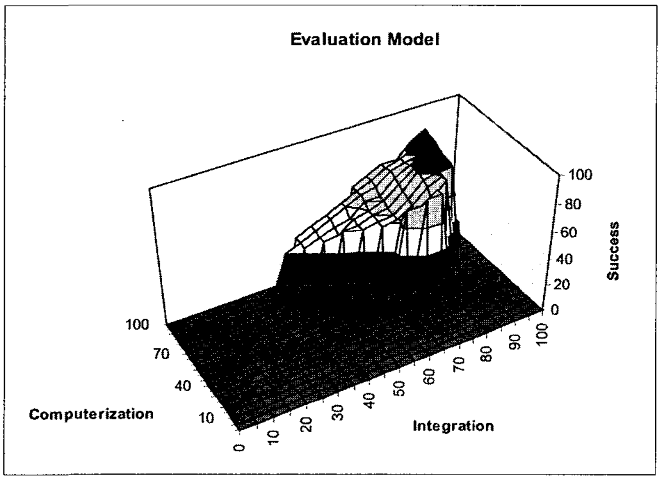

Figure 3: The 3D Surface Chart of Evaluation Model

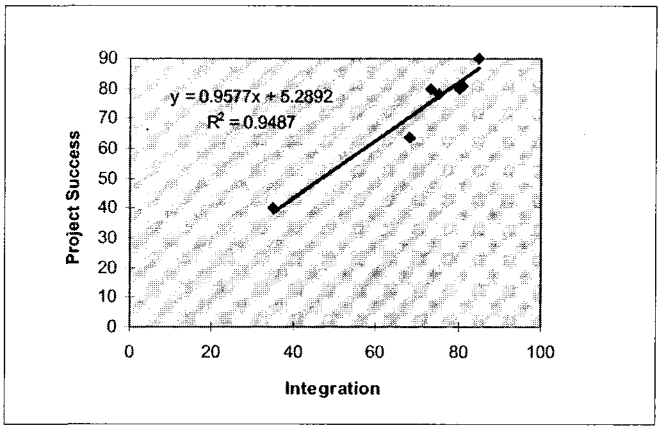

Figure 4: Correlation between Project Success and Integration

showed negative coefficients.

The cross table analysis is the investigation of identifying correlation between variables and attributes. Table 3 to 5 summarizes the covariance and coefficient of determination of each attribute of integration, project success and computerization.

Table 3: The Summary of Cross Table for Project Success vs. Integration Attributes

Attributes of Integration	Covariance	Coefficient of Determination
Congruence	10.5	0.76
Coordination	8.3	0.72
Communication	8.7	0.60
Confidence	5.7	0.58
Competence	7.2	0.57
Commitment	6.0	0.39

To achieve good integration among the participants, congruence known as "alignment of goal" was found the most important attribute.

Table 4: The Summary of Cross Table for Project Success Attributes vs. Integration

Attributes of Project Success	Covariance	Coefficient of Determination
Quality	0.13	0.96
Participants' Satisfaction	0.05	0.79
Schedule	0.07	0.71
Budget	0.12	0.70
Safety	0.21	0.37

It is observed that integration has a strong correlation with quality of a project. It seems that good integration can contribute to the quality of the product.

Table 5: The Summary of Cross Table for Integration Attributes vs. Computerization

Attributes of Integration	Covariance	Coefficient of Determination
Communication	11.26	0.38
Coordination	7.3	0.30
Confidence	8.3	0.19
Competence	1.4	0.01
Congruence	-6.0	0.03
Commitment	-15.3	0.13

It is observed that there is still no strong correlation between attributes of integration and computerization. However, it seems that computer technology may assist Communication and Coordination among the attributes of integration.

7. Conclusion

It is likely to say that integration plays an important role on project success, because integration has a strong correlation with project success. Therefore, a good integration is highly recommended for the enhancement of project success. Especially, a good integration seems to improve quality of a project. There is a recent report[7] from CIFE that integration is a key parameter to measure the quality of facilities. They suggested that there is an emphasis on an increased integration in the facility development to achieve higher quality facilities. Thus, the integration can serve as benchmark of the performance of the project development.

When a good integration was accompanied by the high use of computers, overall project success was increased. This may imply there are still merits of computer technology. It seems that computer technology contributes the project schedule in the way of increasing efficiency by accelerating the design process. Computer technology seems to allow the project participants to acquire necessary information on time with more accuracy. It was disclosed that the successful projects utilized the computer technology in such areas as Design and Communication, mostly which are related to the speed of design process.

The overall impression of trends is that the industry is approaching more integrated and computerized way because the high use of integration and computerization can bring the higher project success. It is predicted that a typical type of computer technology which can increase the efficiency of the project teamwork (the process) will be more utilized. This technology is primarily communication technology. Communication technology allows the participants of a project from different places and different times, with different tasks to work together in such a way as if they work together at the same time. This technology makes it possible to enhance teamwork with the speed and accuracy. The expedient use of communication technology is now becoming an important component demanded by sophiscated owners in the management of their construction projects.

7. Kelly Jean Fergusson and Paul M. Teicholz, "Achieving Industry Facililty Quality: Integration is key", Journal of Management in Engineering, January 1996.