Master Builder Project Delivery System and Designer Construction Knowledge

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Abstract: The master builder system for designing and building construction projects was the dominant project delivery system in the construction industry during the early part of the 20th century. Master builders were generally charged with both design and construction services for a project. During the last half of the 20th century, many different systems for project delivery with fragmented responsibilities have replaced the master builder system. Reducing the use of the master builder system has led to the creation of elaborate systems for managing projects in the construction industry. In order to investigate the use of the master builder delivery system and other systems, a research project was conducted that included reviewing (1) the history of the construction industry, (2) project delivery systems, (3) constructability issues, (4) construction industry fragmentation, (5) the results of a survey of architecture, engineering, and construction professionals from the San Francisco Bay Area in California on the current processes they use for training engineers and architects, (6) an analysis of the survey results, (7) construction industry recommendations, and (8) conclusions based on the survey results and analysis. The information obtained from the research project, including the survey and an analysis of the results, is included in this document. The results of the research indicate that reduction in the use of the master builder project delivery system and the rise of numerous fragmented delivery systems have limited the designer's knowledge of construction processes.

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Introduction

This article provides information on the different types of project delivery systems, the impact of changing project delivery systems including the master builder system, a brief synopsis of the history of the construction industry, constructability issues, and problems with architectural/engineering/construction (A/E/C) industry fragmentation. The information provided demonstrates how changes in the industry have affected the ability of designers to obtain appropriate construction knowledge. The research also generated recommendations for reviving the master builder project delivery system as it may help improve construction project results.

Members of the construction industry must deal with many different types of problems, most of them related either to design processes or to the management of construction projects. Constructability, different types of project delivery systems, and construction management are areas that have received much attention in recent years. Incorporation of constructability reviews into the early design stage of projects may help improve designs. The results of several research investigations have indicated that contractors and construction managers should provide constructability information during the design of a project (''Can your design be built'' 1986; CII 1986; ASCE 1991; Gibson et al. 1995; Hanlon and Sanvido 1995; Fischer and Tatum 1997).

This article summarizes the research conducted to investigate project delivery systems along with information on the scope of the research, the methodology used for the project, the project objective, the purpose of the research, and a discussion on construction management methods. The research was conducted to help establish guidelines on how to improve designers, knowledge of construction processes and to provide information on how to create more efficient techniques for managing construction projects.

Objective

The objective of the master builder system and designer construction knowledge research project was to investigate the history of project delivery systems from the master builder system to the design/bid/build, construction management, and design/build systems to determine if a relationship exists between the changes in project delivery and the construction expertise of designers.

Scope of Work

The scope of this research project included reviewing historical information on the master builder project delivery system, investigating designer construction knowledge, comparing and contrasting different project delivery systems, and investigating construction industry fragmentation.

To reduce the scope of this research, it was limited to architects, contractors, and civil engineers rather than include all de-

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sign professionals. In addition, because the research was self-funded, the survey was distributed to 291 individuals, and only to A/E/C professionals that work in firms in the San Francisco Bay Area of California. This research project included a survey of executive personnel, senior level management and entry-level architects, construction personnel, and civil engineers. A cross section of firms was selected to participate in the research, including different-size firms and firms performing different types of work. A survey was used to minimize the time required for obtaining the required information.

Research Hypothesis

The following, research hypotheses were investigated for this project:

1. It is important for design professionals to have education and training in the areas of construction methods and processes prior to starting a design career; and
2. Design firms do not provide enough training for design professionals on construction methods and processes.

Survey Methods

The survey used for this research investigation included four sections and 32 questions. The different sections were divided into (1) demographic questions about the survey participants and the firms for which they work, (2) information on company training programs, (3) information on project delivery systems, and (4) information on construction and design experience.

Section I of the survey consisted of demographic questions on the type of firm, years of employment, level of education, current title/position, professional registration, revenue of the firm, and number of employees in the firm. The purpose of these questions was to ensure that the respondents came from diverse employment backgrounds.

Section II of the survey consisted of questions on company training programs. This section requested information about the types of training related to construction conducted by company employees (formal and on the job); the subjects of the training programs; respondents' membership in professional or trade organizations; and the number of professional or trade seminars attended by the respondents. This section also, requested information about whether visiting construction jobsites was a job function and what types of duties were performed during these visits. The purpose of these questions was to determine the level of training companies provide and whether the survey respondents were staying current with construction methods, practices, technology, and materials.

Section III of the survey consisted of questions on project delivery systems. This section requested information about the types of project delivery systems the respondents had participated in at work, the percentage of the firm's revenue generated by project delivery system type, whether a firm had a particular preference for one type of project delivery system, and whether the participants were familiar with the term master builder and its definition.

Section IV of the survey consisted of questions on construction and design experience. This section asked respondents to provide responses to questions about construction field experience, construction methods, construction processes, construction management, professional registration, and errors and omissions insurance and how these relate to construction field experience. This section also requested that the respondents identify what levels of construction field experience would enhance design capabilities and the educational requirements for construction knowledge.

A total of 291 surveys were distributed and a total of 89 responses were returned for a response rate of 30.6%. Due to the excessive length of the survey it is not included in this article, but the questions are included in the results section along with the responses obtained for each question.

Literature Review

This section provides a summary of the information obtained during the literature review for this project.

History of Construction in the United States

The first European settlers established the construction industry in the United States, and the first projects constructed in the United States were built in the early 17th century. The construction industry became organized in 1724 by the Carpenters Company in Philadelphia, which was the first formal establishment of the master builder concept in the United States (Condit 1982). Master builders are responsible for designing, surveying, laying out, and managing of construction projects according to the contract documents. In essence, a master builder is the architect, engineer, and job superintendent for each project. In the mid-18th century other master builder organizations were established in New York and Boston. During the late part of the 19th and the early part of the 20th century, the function of the master builder fragmented into designer and constructor specialties, which led to a reduction in the use of the master builder system for building projects (Konchar and Sanvido 1998).

Project Delivery Systems

Many previous research projects on project delivery systems conducted by organizations such as the Construction Industry Institute (CII), ASCE, and the American Institute of Architects (AIA) are available (Vardhan and Yates 1989; AIACC 1996; Konchar and Sanvido 1998). This investigation used three of the project delivery systems identified by the American Institute of Architects California Council (AIACC 1996): traditional, construction management, and design/build.

Traditional project delivery systems include design/bid/build and the negotiated select team project delivery systems. In the design/bid/build system, the owner of a project has separate contracts with a design firm and a construction firm; while in the negotiated select team system the owner hires the project team before the final cost of the project is known, based on the general conditions for the project and a negotiated fee.

In the construction management system the construction manager (CM) could be an advisor, an agent, or a constructor (AIACC 1996), and in the construction manager as an advisor system, the owner has separate contracts with the CM advisor who is their agent, the designer, and the contractor. As with traditional systems, all other parties have noncontractual relationships with each other (AIACC 1996).

The design/build project delivery system consists of the design/build, design/build as developer, and bridging project delivery systems. In design/build project delivery systems an owner contracts directly with a design/build entity for both project design and construction.

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The three AIACC project delivery systems all offer advantages and disadvantages for the owners of projects. Even though the most prevalent project delivery system for construction is the traditional design/bid/build system, all the other project delivery systems are also used within the construction industry.

Industry Fragmentation

Construction industry fragmentation happens in two different areas. The first area of fragmentation is caused by the separation of the master builder function into separate design and construction functions, and the second results from the specialization of designers and builders into more specific fields of operation. Examples of this are the different specialties of engineers and architects that are required to design different aspects of a project such as interior designers, civil, electrical, mechanical engineers, and soon, and the contractors and different subcontractors that build a project (Pocock et al. 1996). As Puddicombe (1993, p. 245) stated in ''Designers and Contractors: Impediments to Integration''

> In the building industry these barriers (fragmentation) can be much more difficult to surmount. The separation between design and construction is much deeper than that between functional departments. Here we deal with separate companies with widely divergent cultures.

Fischer and Tatum (1997, p. 37) noted in ''Characteristics of Design—Relevant Constructability Knowledge''

> Constructability input is hindered by the partial understanding of construction requirements by designers, the fragmented delivery process, contracting practices, diverging goals between design and construction professionals, and changes in construction methods and materials.

Designer Construction Knowledge

As part of this research project the area of designer construction knowledge was investigated to determine whether designers have adequate knowledge about construction methods and processes to effectively design structures. Other research projects have addressed constructability issues, construction project delivery systems, and construction industry fragmentation, but only a limited amount of research is available on the knowledge designers possess about construction methods and techniques and the importance of this knowledge for the success or failure of a project.

Only a small portion of contemporary construction research addresses the shift from designer-controlled projects to projects controlled by other industry professionals. Most existing research deals with the contractor rather than the project designers providing construction knowledge. Based on previous research, it appears that the construction industry has changed from a system of master builders in the 19th century to a fragmented industry composed of owners, project managers, designers, construction managers, and contractors in the 20th century. In addition, construction industry fragmentation has contributed to a reduction in the input of design professionals during construction, which in turn has led to a reduction in their construction knowledge.

Most of the publications that address constructability do not state that designers should obtain a certain level of construction expertise prior to starting a design career. These sources often cite contractors or construction managers as the main source of constructability information and reviews (O'Connor et al. 1986; Vlatas 1986; Kirby et al. 1988). Only a few references mention that designers may lack quality construction knowledge and that this lack of designer construction knowledge may contribute to construction delays, failures, and design errors (Fischer and Tatum 1997).

ASCE (''Can your design be built'' 1986, p. 46) quoted George Reider of Constructability Consultants, Ltd: ''Many design engineers have never been out in the field and cannot visualize the labor and equipment flow required to perform the project.'' Paulson (1976, p. 591) also notes that ''Knowing how to package separate construction contracts along recognized trade and jurisdictional boundaries, as well as accurate knowledge for estimating time and costs for different operations, are essential. Few design consultants really have such capabilities.'' As Uluatam (1992, p. 75) stated in ''Civil Engineering Experience and Education,'' ''It can be strongly advised that civil engineering students have at least a total of six months summer practice on a construction site, which will constitute the first experiences of their professional life.'' As Meryle Secrest (1993, p. 398) stated in *Frank Lloyd Wright: A Biography*

> More to the point, perhaps, Wright's concept of what was basically an arts and crafts workshop was being launched at a moment when the concept of the architect was changing, in common with a general shift toward professionalism, from the idea of master builder and toward the theoretical and scholarly. His insistence upon the importance of direct experience and an apprenticeship to the master must have seemed almost an anachronism.

As noted by Chadwick (1986, p. 76) in ''Impact of Design, Construction and Cost on Project Quality'' a knowledgeable on-site representative of the design firm is ''invaluable.'' Unfortunately, many projects today do not have an on-site design representative, and this lack of on-site observation eliminates an important method for designers to observe the construction process and acquire construction knowledge.

In addition to not being formally trained at a construction jobsite, many architectural and civil engineering students complete only a few construction courses in their college programs. As Oglesby (1982, p. 606) notes in ''Construction Education: Past, Present, and Future,'' ''Most educators in the four year civil engineering programs admit that their programs do not give much attention to construction.'' The changes that have taken place in project delivery systems during the later part of the 20th century may have affected the construction industry in terms of the quality and cost of a project. The research project on the master builder project delivery system and designer construction knowledge provides information on how the industry might be able to improve designer construction knowledge and project delivery systems to reduce construction project costs, and improve schedules and quality.

Survey Results

This section contains the results obtained from the data collected from the survey respondents.

Demographic Information

The survey results were first tabulated by company type, and the results are shown in Table 1; the surveys were also tabulated by the number of years of employment, and the results are shown in Table 2; and the third tabulation summarized the surveys by level of education, and Table 3 shows the results for this question. The results of the survey showed that 43% of the respondents had a professional license, 50% had an architectural license, and 50% had a professional engineering license.

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Table 1. Types of Companies of Survey Respondents

Type of company	Percentage of respondents (%)
Construction contractors and specialty subcontractors	25.8
Construction managers	4.5
Designers from architectural firms	34.8
Designers from engineering firms	19.1
Designers from multidiscipline design firms	6.7
Property managers or owners	7.9
Other types of firms	1.1

For the fifth tabulation the surveys were grouped by the size of the firm, which was determined by the firms annual revenue. Table 4 contains the annual revenues of the firms that the survey respondents worked for when they filled out the survey. For the last tabulation, the surveys were grouped by the size of the firm by number of employees; Table 5 shows the results.

Company Training Programs: Formal and On-the-Job Training

The survey requested information from the respondents about any training programs used by their companies. The two major types of training programs used were formal and on-the-job training programs. Table 6 contains the types and percentage training programs used by companies.

The survey responses indicated that 74.0% of the companies that participated in the survey do not have formal training programs; 60.3% use on-the-job training methods; 39.7% do not offer on-the-job training; 36% use neither formal nor on-the-job training methods; and 23.4% use both training methods.

The survey requested that the respondents indicate the types of training (formal and on the job) offered by their companies. The respondents indicated that their firms provide training in the following areas:

- Codes and specifications;
- Computer technology;
- Construction methods;
- Construction materials;
- Company policies;
- Constructability;
- Construction management;
- Design;
- Maintainability;
- Project management;
- Project relationships; and
- Safety.

The areas of formal training cited as the most common to the least common were

- Codes/specifications (23.8%);
- Computer technology (20.2%);
- Company policies (16.7%);
- Project management (13.1%);
- Safety, construction materials, and design (9.5%);
- Construction methods (8.3%);
- Construction management (7.1%);
- Constructability (4.8%);
- Project relationships (3.6%); and
- Maintainability (2.4%).

The areas of on-the-job training cited as the most to least common were

- Codes/specifications (47.6%);
- Project relationships (39.3%);
- Construction materials (38.1%);
- Company policies and construction management (36.9%);
- Constructability (33.3%);
- Computer technology (26.2%);
- Project management, maintainability, and construction methods (19.1%);
- Safety (17.9%); and
- Design (9.5%).

The survey asked respondents to identify standard activities that they performed when visiting jobsites, and the responses indicated that designers most commonly performed the following:

- Documenting activities (83%);
- Resolving constructability issues (81%);
- Resolving plan and specification conflicts (63%);
- Observing unique construction (61%);
- Working on punch lists (57%);
- Planning and coordination (44%);
- Inspections and change-order processing (43%);

Table 2. Number of Years of Employment of Survey Respondents

Years of employment	Percentage of respondents (%)
1–5 years	12.4
5–10 years	12.4
10–15 years	10.1
15 years or more	64.0
Other	1.1

Table 3. Level of Education of Survey Respondents

Level of education	Percentage (%)
High school education	21.4
Bachelor's degree in architecture	26.2
Bachelor's degree in engineering	13.1
Bachelor's degree in area other than architecture or engineering	14.3
Master's degree in architecture	6.0
Master's degree in engineering	8.3
Master's degree in area other than architecture or engineering	8.3
Doctorate degree or higher education with area not identified	2.4

Table 4. Annual Revenues of Firms

Annual revenue of firms	Percentage of respondents (%)
Below 10 million dollars	60.7
Above 10 million dollars and below 50 million dollars	28.6
Below 100 million dollars but above 50 million dollars	4.8
Below 1 billion dollars but above 500 million dollars	2.4
Other	3.6

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Table 5. Size of Firm of Respondents

Firm size	Percentage of respondents (%)
50 or fewer employees	54.8
Less than 100 but over 50 employees	23.8
Less than 500 but over 100 employees	14.3
Less than 1,000 but over 500 employees	1.2
More than 1,000 employees	6.0

- Assisting others (35%);
- Contract compliance (33%);
- Scheduling (24%);
- Estimating (9%); and
- Safety issues (7%).

Project Delivery Systems

Section III of the survey asked the respondents to provide information on their experience working with different project delivery systems and their preferences for a particular delivery system. The first question in Section III asked the participants to identify the project delivery systems that they had participated in at work. The following are the percentages the respondents indicated on their participation in various project delivery systems:

- Construction management (50.56%);
- Design/build (70.79%);
- Design/bid/build (77.53%);
- Fast track (68.54%);
- Force account (28.09%); and
- Joint venture (22.47%).

Section III also inquired as to whether the respondent's company has a particular preference for or endorses a particular project delivery system. The following are the percentages of the companies that preferred a particular project delivery system:

- Design/bid/build (negotiated) (45.2%);
- No preference (21.4%);
- Not sure (15.5%);
- Construction management (7.1%);
- Design/bid/build (competitive) (6.0%); and
- Design/build (4.8%).

Master Builder Term and Definition

The survey also requested information regarding the respondent's knowledge about the term master builder and its definition. In Section III, question number 4 was ''Are you familiar with the term Master Builder?'' The respondents indicated that 57.1% were familiar with the term. The survey also requested that the respondents pick a definition that best describes their understanding of the term master builder.

- A project delivery system that includes all parties involved in a construction project from concept to operation (24.6%);
- An old construction industry term that is no longer applicable to the construction industry (21.7%);
- Design firms with highly trained and educated architects and engineers that have extensive knowledge of both design and construction that also provide construction services (33.3%);
- Contractors that employ designers to handle all phases of a project from concept to operation (10.1%); and
- Construction and design firms that perform projects via design/build project delivery (10.1%).

Table 6. Types of Training Programs Used by Companies that Participated in the Survey

Types of training programs	Percentage that use training programs (%)
No formal training programs	74
On-the-job training	60.3
Neither formal nor on-the-job training	36
Both on-the-job and formal training	23.4

Construction and Design Experience

Section IV of the survey contained a series of questions related to construction field experience, designer construction knowledge, and design processes; 66% of the respondents thought it important for designers to have construction field experience prior to starting their design careers; 91% thought it important for designers to learn about construction methods, construction processes, and construction management as part of their formal education; 76% thought designers should be required to obtain construction field experience prior to receiving professional registration; and 79% felt that the amount of claims against a design firm's errors and omissions insurance would be reduced if designers had construction field experience.

Question 5 asked respondents to select the most important factor that contributes to effective construction documentation. The most common response to this question was that architects and engineers with extensive construction experience could produce the most effective documents (45%); the second most cited response was that allowing the constructor to be involved in the design from conceptualization would produce the most effective documents (21%); the third response was that having the constructor involved after conceptualization to produce the best construction documents (20%); the fourth response was that architects and engineers with some construction experience would produce the best documents (11%); 1% felt that having extensive design experience would produce the most effective documents; and 1% did not respond to question 5.

Question 6 inquired as to what level of construction experience the respondents would recommend for designers: 67% recommended that designers receive 1 to 3 years of construction field experience; the second most prevalent response was to have designers receive 3 to 5 years experience (13%), and 13% felt that less than 1 year of experience was needed; the fourth response was that no construction field experience was required (3.6%); the fifth response was that it is important for designers to have between 3 and 5 years of construction field experience (1%); and 2% of the respondents did not reply to this question.

The responses to question 7 showed that 43% of the companies do not provide any construction training, and formal training programs were not used as frequently as on-the-job training programs.

Question 8 asked respondents to select the experience level of an on-site construction project observer/participant that would best enhance design capabilities: 50% felt it would be best to have experience on five or more construction projects; the second response endorsed experience on one to five construction projects (44%); the third response wanted experience to be limited to oc-

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casional jobsite visits as required (2%); the least common response was that no experience was needed (1%); and 2% of respondents did not answer this question.

The ninth and final question requested that respondents select the level of construction exposure that is important for designers to receive during their education. The most common selection was one to three required courses (45%); the second was three or more courses, electives, and required courses (21%); the third was that three or more courses should be required (20%); the fourth was no courses (1%); and 1% of the respondents did not answer this question.

Nondesigners were 1.7 times more likely not to join professional organizations. However, nondesigners had a higher rate of joining only one professional organization than designers (26 versus 20%); also, nondesigners joined more than two or more professional organizations 1.57 fewer times than designers. An inverse situation occurs when membership rates are compared for trade organizations. Design professionals were almost 3 times less likely to belong to a trade organization, and in addition, designers were 4.23 times less likely to belong to one or more trade organizations. These results indicate a much larger percentage of nondesigners joining trade organizations than designers joining trade organizations.

Survey Analysis

Training Programs

One part of the survey addressed the use of training programs and their use in A/E/C firms. This section explored the importance of training activities related to construction and how firms encourage additional knowledge acquisition. The survey provided questions to help determine the importance of construction knowledge for design engineers and architects.

The survey results showed that only 23% of the members of the firms participating in this research survey have both formal and on-the-job training programs (60% use on-the-job training). Of the firms that do not do design work (contractors, construction managers, other, and owner/property managers), 23% have formal training programs, and of the design firms (architects, engineers and multiple design), 22% have formal training programs. The survey results also indicated a correlation coefficient of 0.99 and a coefficient of determination of 0.99, which indicated that both the design and nondesign firms use formal training methods in similar proportions.

The survey results indicated that 60% of all firms use on-the-job training programs, and 49% of the nondesign firms and 41% of the design firms employ this training method. This 8% difference is significant in that design firms used this method at a lower rate than nondesign firms. It is also significant that the overall rate of on-the-job training of 55% is twice the formal training rate for all respondents. One explanation for this difference was provided by one of the respondents:

> Currently the colleges/universities provide the background education concepts, how to think like an engineer, basic sciences and materials technology. The student pays for this education. The firms provide more practical knowledge—how to prepare calculations and design documents, construction field experience. The firms pay for this, but often the individual doesn't stay with the firm long enough to allow the firm to recoup the cost of education. Either the student must pay more for the education (shift some of the practical training to the schools) or the firm's fee must be increased to pay for this training. For smaller firms that feel they cannot set up formal training, consider training set up jointly by several firms perhaps utilizing a professional organization or local college/university. This might be especially valuable for construction field training.

Many of the respondents felt that their firms do not provide enough formal and on-the-job training. Evidence of this was shown by the numerous comments provided in the surveys. Listed here are several comments from respondents related to the training programs used by their firms:

> Yes, it is way better to have construction/on-site experience, as much as possible, but you are lucky or not if you get it. It should not be obligatory.
>
> Mentoring, mentoring, and mentoring.
>
> I think designers should learn about architecture during school. Drafting and construction after graduation or during intern years at an architecture firm. Most large firms will not give you that and only a select few small/medium size firms will provide that education. Probably best for architecture students to work construction for a few years prior to working as a designer.
>
> I think you are right about field experience but, how to find time to allow everyone to participate is the trick. Maybe courses that involve credit for apprenticeship, while at school, with local firms.
>
> No formal on the job training is provided, catch as catch can.
>
> Sink or swim mentality.

The respondents were also asked to provide information about specific areas of training, both formal and on the job, and these areas included constructability issues, construction methods, construction materials, construction management, and design. The surveys revealed that for firms using formal training methods the nondesign firms used formal training methods 1.15 to 3.09 times more often than design firms. However, design firms used on-the-job training methods more frequently then nondesign firms, from 1.1 to 10 times more frequently. Combining the two training types revealed that design firms provide training more frequently then nondesign firms. In most cases design firms provided two times more training than nondesign firms. Combining both types of training indicated that design firms train their personnel more frequently in the areas of constructability issues, construction methods, construction materials, and design from 1.35 to 4.67 more frequently than nondesign firms. However, nondesign firms train their employees in the area of construction management at 1.29 times the rate for design firms.

The distribution results were analyzed using Pearson's product moment correlation (r), the coefficient of determination (r-squared or RSQ), and the level of statistical significance tests. The results for the different types of formal training showed an r-value of 0.658 and an RSQ of 0.433. These results indicated a strong correlation, a high RSQ value, and statistical significance, which means that both designers and nondesigners use formal training methods in a similar manner.

However, these tests produced dramatically different results when used with the on-the-job training results. The r-value for the on-the-job training is 0.146, and the RSQ is 0.021, which means that the on-the-job training results show a very low correlation, a weak RSQ, and little statistical significance, indicating that design firms have far more on-the-job training programs, and nondesign firms tend to provide more formal training programs. It was also evident that these two types of firms use formal training methods

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in a similar manner and proportion, but there is minimal commonality for on-the-job training methods. However, design firms provide more training opportunities for their employees.

Professional and Trade Organizations

Participation in professional and trade organizations is one indication of the level of importance designers and nondesigners place on staying current with industry trends and new technology, therefore it is important to identify the relationship between design and nondesign firms in the responses related to participation levels.

In addition, the distribution results were subjected to a correlation analysis using product moment correlations, the coefficient of determination, and the level of statistical significance. The results for the membership in professional organizations showed an *r*-value of 0.066 and an RSQ of 0.004, which indicates weak correlation, an extremely low RSQ value, and little statistical significance. In addition, the *r*-value for trade organization membership is 0.194 and the RSQ is 0.04, which shows a low correlation, a weak RSQ, and little statistical significance. These types of correlation results should be expected because designers tend to join professional organizations, and nondesigners tend to join trade organizations.

The differences in membership are also reflected in the rate at which designers and nondesigners attend professional and trade seminars. The survey results showed that nondesigners had a rate of 2.18 times higher for not attending professional seminars than designers. In contrast, nondesigners had a 2.5 times higher rate of attending at least one seminar than designers and nearly equal rates of attendance for one to three and three to five professional seminars over a 3-year period. Designers attended five or more seminars at a rate 3.11 times higher than nondesigners. In addition, designers had a 1.95 times higher rate of not attending any trade seminars than nondesigners. Both designers and nondesigners had equal rates of attending at least one trade seminar.

Designers were slightly more than two times less likely to attend one to three trade seminars and were nearly equal in attending three to five trade seminars or more over a 3-year period. This trend further supports the theory that designers are less likely to acquire construction knowledge than their nondesign counterparts in the construction industry, but it also supports the idea that nondesigners are more interested in design issues than designers are interested in construction issues.

In addition, a correlation analysis using a product moment correlation, coefficient of determination, and level of statistical significance was performed on the professional and trade organization seminar distribution, and the results for the attendance of professional seminars showed an *r*-value of 0.579 and an RSQ of 0.336. The results indicate a moderate correlation, an intermediate RSQ value, and statistical significance. In addition, the *r*-value for trade organization seminar attendance is 0.402, and the RSQ is 0.161. These trade organization correlation results showed a moderate level of correlation, an intermediate RSQ, and statistical significance. These types of correlation results mean that designers and nondesigners attend trade and professional seminars in similar proportions and frequency.

However, the overall results still indicate that a large number of designers and nondesigners do not use this method for obtaining additional technical knowledge. Because designers are less likely to participate in trade organizations, the results support the hypothesis that designers do not consider construction training as important, or required, to produce good designs as do nondesigners.

Jobsite Visits

The survey revealed that both designers and nondesigners have a strong requirement/obligation to visit jobsites as part of their work: 95% of the respondents work for companies that encourage them to visit jobsites. This process does not however guarantee that designers are learning construction techniques or processes to augment their design training.

Two of the three highest responses indicated that designers are spending a higher percentage of their time at the jobsite resolving issues related to their designs. It is interesting to note that the three lowest designer responses—scheduling, estimating, and safety—are for activities that nondesigners perform at a much higher rate. Another interesting result is that the response rates for designers ranged from a high of 83% for documentation to a low of 7% for safety, while nondesigners ranged from a high of 54% for constructability, planning and coordination, and estimating to a low of 28% for documentation. This indicates that nondesigners spend more time on all items equally while designers concentrate on fewer areas.

Correlation analysis of the jobsite visit results revealed that both designers and nondesigners have an *r*-value of 1.00 and an RSQ of 1.00. This indicated a very high correlation, very high shared variance, and statistical significance, which shows that designers and nondesigners consider jobsite visits an important part of their assignments. Correlation analysis of the types of activities performed during jobsite visits by designers and nondesigners revealed an *r*-value of -0.119 and an RSQ of 0.014, which means low correlation, low shared variance, and no statistical significance. These correlation results mean that both designers and nondesigners find jobsite visits important but perform dramatically different functions during these visits.

Project Delivery System Participation

The survey requested participants to identify the different types of project delivery systems they have been involved with on construction projects. The results obtained from this question showed that the designers and nondesigners have both participated in design/build and design/bid/build project delivery systems at relatively equal rates: 72% for designers versus 69% for nondesigners for design/build, and 76% for designers and 80% for nondesigners for design/bid/build type projects. These results are significant in that these project delivery systems tend to provide designers with greater access to construction input during the design phase.

The survey requested that the respondents list their preferred project delivery system. The results obtained for this question indicated that designers and nondesigners preferred the design/bid/build (negotiated) method: over 50% of the nondesigners and 40% of the designers preferred this delivery system method. However, 26% of the designers and 14% of the nondesigners indicated that they had no preference for one system over another, and 18% of the designers and 11% of the nondesigners were not sure if they had a preference. All other project delivery systems were indicated by fewer then 12%, with most of the remaining systems receiving less than 6% of the responses.

In addition, the distribution results were analyzed using correlation analysis with product moment correlations, coefficient of determination, and level of statistical significance tests. The results for delivery system participation showed an *r*-value of 0.925

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and an RSQ of 0.856, which indicated strong correlation, extremely high shared variance, and high statistical significance. In addition, the *r*-value for delivery system preference was 0.859 and the RSQ was 0.739, which indicated that these results showed a high correlation, moderate shared variance or RSQ, and statistical significance. The results obtained indicated a preference by both designers and nondesigners to work in collaborative project delivery systems, which supports the research hypothesis that designers should obtain construction knowledge to improve designs.

Master Builder Term and Definition

The survey also requested respondents to answer the question of whether they were familiar with the term master builder and its definition. The survey results indicated that 63% of the designers and 49% of the nondesigners were familiar with the term master builder.

The results also revealed that 24% of the designers and 25% of the nondesigners indicated that the term master builder means ''A project delivery system that includes all parties involved in a construction project from concept to operation''; 36% of the designers and 7% of the nondesigners indicated that a master builder is ''An old construction industry term that is no longer applicable to the construction industry''; 27% of the designers and 39% of the nondesigners indicated that a master builder is ''Design firms with Architects or Engineers highly trained and educated that have extensive knowledge of both design and construction that also provides construction services''; 7% of the designers and 14% of the nondesigners indicated that master builder means ''Contractors that employ designers to handle all phases of a project from concept to operation''; and 14% of designers and 7% of nondesigners indicated that Master Builder means ''Construction and design firms that perform projects via the Design/Build project delivery system.''

The results obtained for the question on the definitions of master builder showed an *r*-value of 0.16 and an RSQ of 0.026, which indicated weak correlation, weak shared variance, and statistical significance. The correlation analysis indicated that designers and nondesigners do not agree on the definition of Master Builders. In addition, the results indicated that designers think that the term master builder is not as relevant to the current construction industry, and 36% indicated that the term is no longer applicable, more nondesigners were able to properly define the term master builder, while 39% indicated that the term means highly trained and educated architects and engineers that perform construction services.

Construction Experience and Design

Section IV of the survey requested information about the construction and design experience of the respondents and how they relate to one another. The first question asked, ''Do you think it is important for designers to have construction field experience prior to starting their design careers''; the second question inquired as to whether ''designers should be required to also learn about construction methods, processes and construction management as part of their formal education''; the third question was on whether ''Designers should be required to obtain construction field experience prior to receiving professional registration''; and the fourth asked ''Do you think that claims against a design firm's errors and omissions insurance would be reduced if designers had construction field experience?''

Over two-thirds of both designers and nondesigners felt it is important for designers to have construction field experience and learn about construction methods and materials prior to obtaining their registration. Over 75% of the nondesigners responded yes to these four questions. The results indicated a need for designers to receive construction training prior to starting the design phase of their careers. Designers also need to learn about construction methods, processes, and construction management during their education. The respondents also indicated that designers should have construction field experience prior to professional registration, and that errors and omissions insurance claims could be reduced if more construction field training was provided to designers.

Questions 1 to 4 in Section IV were combined, entered into a spreadsheet, and analyzed for any correlations among the data. The correlations for questions 1 to 4 showed an *r*-value of 0.786 and an RSQ or shared variance of 0.617, which indicated a strong correlation, high shared variance, and high statistical significance between designers and nondesigners responses to these four questions.

The respondents were also prompted to identify the most important factor that they think contributes to effective construction documentation. The survey results showed that 42% of the designers selected ''Architects and Engineers with extensive construction experience.'' For the nondesigners, 18% selected this option, but 53% of the nondesigners and 19% of the designers selected ''Allowing the constructor to be involved in the design phase from conceptualization.''

The correlation results revealed an *r*-value of 0.18 and an RSQ of 0.032, which indicated low correlation, low common variance, and little statistical significance between the responses from designers and nondesigners. This indicated that designers would prefer a master builder type of delivery system and that nondesigners would support the design/build (negotiated) type of delivery system.

The survey also asked the respondents to identify the level of construction experience that designers should have to produce effective construction documentation. Over 60% of the designers felt 1 to 3 years of construction experience would be appropriate, and over 74% of the nondesigners also indicated this level of experience; 17% of the nondesigners felt that 3 to 5 years would be an adequate amount of training, and 19% of the designers felt that less then 1 year would be adequate. The correlation results showed an *r*-value of 0.968 and an RSQ of 0.937, which indicated that the respondents felt that 1 to 3 years of construction experience would be needed to produce effective design documents.

Question 7 in Section IV asked the respondents to rank the level of construction training that is being provided by their firms. The responses indicated that more then 80% of design and nondesign firms provide limited training and have no formal training programs; 37% of the design respondents and 61% of the nondesign respondents had no training programs. The correlation analysis for this question resulted in an *r*-value of 0.754 and an RSQ of 0.568, which means that members of both design and nondesign firms feel construction training is a low priority, or they do not have the resources to provide this type of training.

Question 8 in Section IV asked the respondents to select the experience level of an on-site construction project observer/participant that would enhance the design capabilities of a designer. Over 40% of both designers and nondesigners felt experience on one to five projects would be beneficial, and over 50% of both designers and nondesigners felt five or more projects would be appropriate. The correlation analysis resulted in an *r*-value of 0.99 and an RSQ of 0.981, which means that designers and nondesigners both agreed that designers would benefit from on-site

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observation and participation, which supports the hypothesis that designers would benefit from construction field experience prior to starting their design careers.

The final question of Section IV asked the respondents to identify the amount of construction exposure that students should have during college: 46% of the designers and 41% of the nondesigners indicated that one to three courses are adequate, but the respondents felt these should be required courses, and 20% of the designers and 26% of the nondesigners thought students should have three or more courses, and these courses could be a mix of electives and required courses. In addition, the correlation analysis for this question resulted in an *r*-value of 0.855 and a high RSQ value of 0.731, which indicated that industry professionals prefer students who have had more than just minimal exposure to construction concepts during their college education.

Recommendations

Based on the results of this research, the following recommendations were developed, which could be used to help improve construction knowledge of designers in the A/E/C industry.

Recommendations for Practical Applications

- Establish construction-training programs for designers prior to the design stage of their careers;
- Increase the number of construction courses taught at universities and colleges that offer architecture and engineering programs. The course work proposed could be a mixture of required and elective classes;
- Establish new requirements by state architect and engineering professional licensing boards for construction training prior to licensure;
- Provide industry support for a hybrid license in all states for a master builder license. Such a license would allow firms and individuals with demonstrated capabilities to offer design and construction services under one license;
- Provide insurance industry recognition of firms and individuals participating in and receiving additional construction training. Such recognition could help reduce errors and omissions rates;
- Provide more A/E/C industrywide recognition for designers that have participated in designer construction training programs in addition to continuing education units. Project owners could use this during a competitive analysis of the firms negotiating for their projects; and
- Increase awareness by members of design firms of how inefficiencies can be corrected by construction training. Well-designed projects could help produce savings in design, construction administration, and close-out man-hours. Design firms with well-established training programs and results could have a competitive advantage over firms that do not provide construction-training programs.

Future Research Recommendations

The following areas are suggested for further research:

- Research on insurance industry errors and omissions insurance standards and establishment of rates based on construction experience factors;
- Research on unified master builder project delivery system requirements and investigation of benefits to the A/E/C industry; and
- Nationwide surveys similar to those used in this research to identify and/or confirm trends or results similar to the data obtained for this research project.

Conclusions

This article included sections on U.S. construction industry history, research methodologies, a literature review of relevant construction industry publications, results from a survey of construction industry professionals in the San Francisco Bay Area about designer construction knowledge, an analysis of the survey results including statistical information, a literature review, and recommendations based on the survey results.

The survey results and an analysis of the results confirmed the first research hypothesis since a high percentage of the respondents felt that designer construction knowledge obtained prior to starting a design career is important. The results also confirmed the second research hypothesis because many of the respondents did not think that design firms provide enough training for their employees, and many engineering and construction professionals are not members of professional or trade organizations, which limits their opportunities for staying current with industry trends and their access to a source of construction training.

Personnel from A/E/C firms support or require visits to jobsites, which indicates that designers have some opportunities for acquiring construction training and knowledge. Jobsite visits do not however ensure that designers will receive or acquire appropriate training. The survey results indicated that designers tend to perform tasks at the jobsites related to resolution of design problems rather than obtaining construction knowledge.

The survey results also revealed that many respondents have been involved with a wide variety of different project delivery systems, which suggests that designers are familiar with the different project delivery methods. However, many respondents, including designers, were not familiar with the term master builder, and even if they were familiar with the term they could not properly define its meaning. This seems to indicate a lack of knowledge regarding the term master builder, which may mean that its meaning is rapidly changing to design build, or it is slowing disappearing from the A/E/C industry.

Finally, the survey and the research results obtained from the A/E/C industry members support the hypothesis of the necessity for designers to receive construction training prior to starting their design careers. Also, designers and nondesigners felt that errors and omissions insurance would be reduced if designers received construction training. The survey also supports that both A/E/C firms and educational institutions should provide opportunities for designers to advance their construction experience or obtain additional knowledge of construction processes and methods.

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