

Product Research & Development in an Academic Collaboration: A Qualitative Case Study

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According to the U.S. Department of Labor, the construction industry has a half-century history of little, if any, overall quantifiable improvement in productivity, as opposed to significant advances in nearly every other occupational sector. Many attribute this flatness to a resistance to new tools, products and other ergonomic improvements. Simultaneously, research in construction management education programs in the U.S. has historically centered around management issues, or construction education itself. Rarely does research and development of products and materials occur within construction management scholarly efforts, illuminating the opportunity for this case study. In it, a collaboration of students and faculty in construction management and industrial design programs was studied, one that partnered with industry end users and manufacturers producing ideas and prototypes having potential to positively impact productivity and safety in the built environment industries. The effort features the benefits of second generational product development for the construction industry, illuminating how iterative problem solving can be successful, as well as tactile and meaningful research vehicles historically absent from construction education.

Key Words: collaboration, industrial design, research and development, construction productivity

Introduction

Improving efficiency is an essential part of maintaining or increasing profitability for many if not most industries, reaching several areas of opportunity, but primarily labor and equipment. This is a continual battle for the construction industry in an effort to improve profits. Most industry segments in the U.S. have seen quantifiable increases in overall productivity in the last half century. However, the construction industry is the only major segment that has failed to do so (Figure 1). In construction, there is significant overlap and duplication with respect to tools and equipment used by various trades.

Universities have often played a role in research and development ("R&D") of products, software applications, processes, etc., and more recently with one of its goals to produce intellectual property for the institution. These partnerships can make for viable and effective collaborations in which students and faculty investigate real industry needs, and also represent an opportunity for private enterprises to make R&D efforts cost effective.

In the academic disciplines within the built environment, there has been a notable increase of collaboration among architecture and construction programs over the past decade. Many institutions have demonstrated successful models that feature interdisciplinary work at their core. These successes suggest that collaboration among other types of academic units might provide different, yet equally successful opportunities.

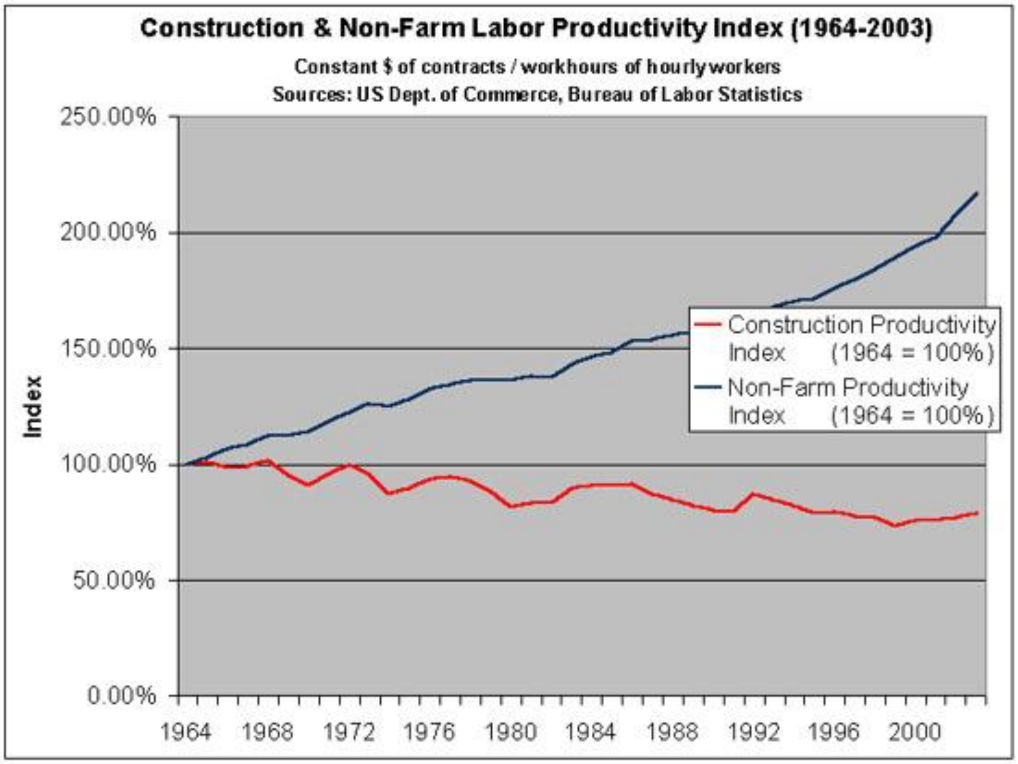

Figure 1

One such effort has been undertaken for the past five years at a major U.S. institution, offering participation in real-world marketplaces, fostering research opportunities valuable beyond scholarly dissemination. The project was a collaboration in which students and faculty from programs in construction management and industrial design work together to solve problems and develop products to improve productivity and safety in the construction industry. More recently, the program has expanded to include leading manufacturers as well as professional end users to further improve the R&D proposition.

In this effort, collaborative academic/industry teams conduct ethnographic research, develop and vet concepts, test and get industry feedback on prototypes, and ultimately produce intellectual property that has the potential to improve the industry, and also to provide licensing opportunities for the institution. As an anecdotal metric, the program is validated by increased interest from manufacturers who now 'compete' for partnership slots, many of whom attest to the value that university R&D provides. Further, these efforts spawn individual opportunities for faculty and students to do post-product development research on efficacy, fabrication, and ergonomic response, in which the private sector has shown significant interest. This type of research is fairly unique among construction management programs, which is often centers around management issues, or education itself.

This paper presents a qualitative case study on one of the output products from the program, illuminating how 'second generational' product development at the academic level can improve performance and propensity to impact the industry. Using a collapsible interior scaffold that is specifically designed to simplify assembly (requiring only one person) as a subject, this study demonstrates the wide potential of the contributions that construction education can make in the realm of university/private sector R&D partnerships, and how second generational efforts create significant value in the development process. Within this context, quantitative evaluation is not the focused metric for the purposes of this study. Rather, the outcomes of this study provide a basis for understanding the potential of the model itself.

Literature Review

Productivity

The construction industry's productivity has been declining since the mid-1960s at a compound rate of -.48% per year (Teicholz, 2001). Teicholz further points out in contrast that all non-farm industries over the same time period show an increase in labor productivity of 1.71% per year. While some researchers assert management ineffectiveness as the principal factor, others look to job-site productivity as a major contributor (Dai, et al. 2009 citing BRT 1983, Sanvido 1988, Kellogg, et al. 1981). Recent data collected from a survey of the craft-worker community, trades of which comprise approximately 54% of the construction workforce (Bureau of Labor Statistics, 2011), indicates "tools" as a top factor affecting job-site productivity (Dai, et al. 2009). While advancements in tool technology have been made, the inherent fragmentation of the industry inadvertently forms barriers which create an inhospitable environment for innovation (Allmon, et al. 2000). Further, construction industry research is virtually nonexistent because the AEC community has little resources or ability to influence innovation and product design (Haskell, 2005). Haskell goes on to suggest that increased collaborative efforts among manufacturers, designers, and constructors can accelerate improvements in productivity.

Academic Opportunity

Mimicking the industry in practice, the design and construction disciplines within academia have historically been segregated in the U.S. (Holley and Emig, 2011). In recent years however, the concept of multidisciplinary collaborative education has become a topic of major priority as the AEC industry is rapidly changing from the traditional design-bid-build model to a more collaborative design-build delivery method (Septelka, 2002). Programs implemented at the University of Washington and Auburn University provides two examples of initiatives taken by higher education institutions to adapt to this change (Septelka, 2002; Holley and Emig, 2011). Various other ad hoc projects have been undertaken by other universities across the country, such as the University of Oklahoma and California Polytechnic State University (Ryan and Callahan, 2007; Montoya, et al. 2009). These projects are reflections of industry advancement of productivity and efficiency affected by integrated management practices.

Initial industry practitioner interaction, common among many of these studies, indicates the models better prepare students for challenges of the industry, and help develop a collaborative discipline early in their career (Montoya, et al. 2009; Holley and Emig, 2011). In addition, a 2003 case study of a Collaborative Sustainable Construction and Design course noted student's discovery of the extent to which design and construction rely on each other to deliver a complete solution (Holley and Dagg, 2005). Through the positive student/ industry feedback, initial successes of these programs suggest a cross-disciplinary collaborative model improves the potential for an increase in management effectiveness within the architecture and construction disciplines. Further, they provide foundational support to consider how a pedagogical model of this type could affect positive change in job-site productivity.

Research and development collaboration between industry and universities is not a new concept (Geisler, 1995). Success of this long-standing partnership is likely due to the potential benefits of both parties (Nasr and AbdulNour, 1997). Universities can benefit from access to alternative funding sources, exposure to real-world problems, and advancement of knowledge (Peters and Fusfeld, 1983). Motivating factors for industry partners may include access to technology, lower R&D costs, and access to technical expertise (Geisler, 1995). However, advancements in technology and information transfer are beginning to change the face of these collaborations. Kanfer et al (2000) state "We are rapidly moving toward a world in which knowledge is constructed collaboratively at a distance by multidisciplinary teams......exponential growth of knowledge has made it nearly impossible for any organization to exist in isolation." Universities are following suit, by stepping across traditional departmental boundaries to form cross disciplinary collaborations in an effort to counteract the isolating silo effect (Pfirman et al. 2005).

Successful product development in the 21st century is widely recognized as being contingent on a solid understanding of consumer need and aspirations (Hoonhout, 2007). Further, the internet has armed consumers with product information and selection never before available. In response to this, industry has identified end-user innovation as key to product success (Flint, 2002). Hoonhout (2007) characterizes end-user innovation as an iterative prototyping process involving consumer feedback in the early stages of development. By providing multiple prototypes early in the development process, end-users can give specific feedback to tangible issues from use of the product (Beyer and Holzblatt, 1997). The iterative development of product prototypes further reinforces the needs and aspirations of the consumer prior to market penetration (Hoonhout, 2007).

Cross disciplinary research is much a function of necessity due in part to the inherent nature of the process being problem-oriented as a reaction to real-world issues that do not come in disciplinary shaped boxes (Jeffrey, 2003). To date, most studies have focused on the motivational factors behind university/industry collaboration (Abramo, et al, 2010; Geisler, 1995) and less about the processes involved. From an academic disciplinary perspective, this type of product development and R&D within U.S. Construction Management programs is rare, illuminating the opportunity for the same.

Methodology and Case Study

The study utilized a multi-phased qualitative approach, first developing potential to address an industry problem, and then based on industry feedback, employing a second generation of development. After the second generational effort, a final phase of prototype testing of models fabricated from different materials was undertaken as part of a follow up internal grant program, yielding qualitative perspective shared in this paper.

In the first iteration in fall of 2009, a combination material cart and rolling scaffold was developed through a collaboration of students and faculty from construction management and industrial design, along with industry end-user partners. It was thought that a device serving as both a material cart and a scaffold would be a desirable product. This would appeal to trades typically working on a building's "interiors" construction or facilities maintenance projects, where the tradesmen work alone a significant part of the time. The effort focused on designing a product that could be prototyped for feedback from other end users (Figures 2 and 3). The result was a test product fabricated from steel components.

Figure 2: First generation scaffold erected

Figure 3: First generation scaffold collapsed into a 'cart'

Once the prototype was completed, both benefits and drawbacks to the current design were solicited and collected on a qualitative basis from tradesmen of multiple disciplines. The product was noted to be one that desirably incorporated two pieces of equipment into one unit; however, it was criticized to be too heavy and too difficult for one tradesman to use efficiently.

In the following year of the product development program (2010), the scaffold was chosen as a select product to be developed in a second generation; a distinction typically held for those products deemed to have future marketplace potential. A new interdisciplinary student team was challenged to take the comments from the first generation and also incorporate any intuitive improvements into a new and improved version of the product. The second generation effort was broken into two sub-phases. Feedback from industry and the academic teams noted weight of the steel as a major issue, constituting the need for an aluminum prototype. However, it was determined other problems identified should be addressed in another steel prototype prior to producing a more expensive aluminum version (Figure 4, in foreground.)

Figure 4 : 2nd Generation steel prototype in foreground

The second generation interdisciplinary team addressed a number of issues. These included structural connections, hardware issues, simplifying the installation of the work platform on the scaffold sides, and improving the handle for use on the cart. Additionally, improving the cart's ability to roll on uneven surfaces, and keeping the uppermost height of the work platform below 6 feet to comply with safety regulations were areas of attention. Specifically, the manner in which the wheels were transitioned from their original material cart position to the scaffold position was studied. The original prototype required one set of wheels to be unpinned allowing the wheels to rotate 90 degrees to the new position. The second set of wheels required relocation to the scaffold position (Figure 3). During second generation development, it was discovered that a more efficient and sturdier design was to simply include a second complete set of wheels to remain in the same position at all times, thereby eliminating the need to move or relocate the wheels (Figure 7). The resulting prototype which included the design revisions to the wheels gained favorable feedback from other academic critics, as well as industry partners. Upon completion of the revisions it was submitted for provisional patent in November of 2010.

Phase II of the '2nd Generation' development included securing a grant to fund the professional fabrication and evaluation of an aluminum prototype. The aluminum prototype was fabricated in the spring of 2011 to facilitate industry feedback over summer and fall semesters. The design featured a unique platform assembly referred to as an 'oven rack,' This design allowed a single user to easily install the working platform from the front in a more ergonomic fashion,. In addition, it could easily collapse and convert the scaffold to a cart for transporting materials (Figures 5, 6 and 7).

Figure 5 : 'oven rack' removal

Figure 6 : Preparing to collapse

Figure 7 : Conversion to cart

Results

The aluminum prototype was then made available for critique, use, and qualitative feedback by select general contractors, trade contractors, facilities maintenance personnel, and rental equipment companies as part of the qualitative analysis. After use on actual construction sites in technical context, key feedback showed overwhelming support of the efficacy and potential of the equipment. All respondents indicated that they would consider using/purchasing such a product if commercially available. Further, they considered the aluminum framing a distinct advantage, and would invest in it at a premium. A majority of respondents indicated noticeable ergonomic benefit because of the lighter weight aluminum. Most either reported or speculated quantifiable improvement to productivity because of its ease of use by one mechanic. All respondents indicated that the ability for it to be converted to a transportation device for interior construction activities was a distinct benefit.

As a result of the second generation development and qualitative industry feedback, the product is now provisionally patented, with plans to soon file non-provisionally, and has garnered the interest of multiple manufacturers and retailers of similar products. In addition, the institution is currently entertaining licensing agreements for the intellectual property.

Summary and Conclusions

As recent collaborations in academia between architecture and construction management have shown, there are distinct advantages in synergistic solutions to problems and tasks within the industry of the built environment. This qualitative case study demonstrates there are also clear opportunities to expand successful collaboration to other related disciplines, particularly those in other types of design.

Participation and validation by industry is a key component in the process, and provides a much needed 'ground' in both the development and testing. It also is demonstrative to students that the contribution of expertise in real problem solving contexts 'shifts' from one party to the next, depending on the need at the time. A correlation might be drawn to collaborative project delivery, in which leadership often is mobile in much the same way.

The success of utilizing a second generational effort was compelling. Often in construction as a practice, opportunities to revise, improve, or refine do not exist, unless done so virtually. Exposure to the benefits of this process on a development project was particularly enlightening to students and faculty alike.

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