Case Study

State of Integration: Investigation of Integration in the A/E/C Community

M. S. Uihlein, P.E., M.ASCE

Abstract: Integrated buildings are one goal of the architectural/engineering/construction (A/E/C) community. Integration implies quality work and it is perceived to add value to a project; but, how is integration defined and how is it applied? This paper reflects on the current status of integration and assesses where the industry stands. To do this, integration was evaluated through publicly available documents of the major professional organizations that represent the field. The American Institute of Architects; ASCE; two ASCE institutes (Structural Engineering Institute and Architectural Engineering Institute); the American Society of Heating, Refrigerating and Air-Conditioning Engineers; and the Associated General Contractors of America were examined for their commitment to and implementation of integration and integrated design. This survey of the resources has found that integration is important to the industry on the whole, but that the effort to include integration into the A/E/C industry varies in commitment by discipline. However, while there is unevenness in the industry toward integration, there is movement to address the complex idea of integration and changes are ongoing. DOI: 10.1061/(ASCE)AE.1943-5568.0000139. © 2013 American Society of Civil Engineers.

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Introduction

Integration of multiple disciplines and architecture has been a topic in the architectural/engineering/construction (A/E/C) community for a considerable period of time. Ove N. Arup, the famous British/Danish structural engineer, discussed the oversuse of the term as early as the 1960s: “Integration and collaboration have been preached ad nauseam…” (Brawne 1983). In 1986, the Building systems integration handbook (Rush 1986) set to address the integration in a conscious, deliberate manner. Today, the value of integration is still touted and remains a goal for the industry. However, the use of the term is varied and often imprecise. What does integration add to a project, how is it practiced, and how is this measured? Yet, there are noticeable shifts happening in the industry, each one with the potential to significantly change the way both practice and integration occur. The last decade has seen Autodesk’s targeted implementation of building information modeling (BIM) across the industry, beginning in 2003 (Autodesk Building Solutions 2003); a series of articles on integrated design and sustainability in 2004; the American Institute of Architects (AIA) “Report on integrated practice” (Brosnahan et al. 2006); and the release of Integrated project delivery: A guide (AIA 2007).

Along with these endeavors, several new terms and ideas have been developed: (1) clash detection, (2) interoperability of multiple three-dimensional models, (3) quick exchange of data, (4) delineation of teamwork, and (5) change in the timing of design in a project. In conjunction with the detrimental effects of the 2008 economic recession, each discipline within the A/E/C community has had to examine the way it works and the products produced.

Integration may no longer be just an idea; it has become a survival mechanism. To this end, it is a good time to reflect on the current status of integration and to assess where the industry stands. Thus, integration is evaluated in this paper through the documents of the major professional groups that guide engineers and architects. If these complementary professions are on the verge of significant changes, the representative organizations are a good measure of the transformation. The commitment and implementation of integration and integrated design are demonstrated through the engagement of these groups. For the purposes of this paper, the investigation is limited to the application of integration during the design phases of the project as opposed to the construction of a building, though construction concerns in design are included.

Methodology, Documents, and the Organizations

This study is an examination of the practice literature and guidelines that are available on the topic of integration. Any meaningful discussion of integration includes hearing from all members of the building team—architects, engineers, and contractors. Accordingly, the work of the AIA; ASCE; two ASCE institutes, namely, the Structural Engineering Institute (SEI) and the Architectural Engineering Institute (AEI); the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE); and the Associated General Contractors of America (AGC) are examined. Each group sets the benchmarks for their members, provides guidance through documents such as standard contracts and technical standards, and enacts programs to benefit the profession as a whole. This paper reviews publicly available information from both print and electronic sources. Documents examined included publications such as journals, standards, handbooks, and professional practice papers. Bylaws, mission, and vision statements also were studied because they represent the ideals of an organization.

ASCE

Integration can be found at a high level within ASCE’s goals for the profession and in a more hands-on approach in two practice guides. In “The vision for civil engineering in 2025,” civil engineers are called to expand their skills and become leaders beyond the field of...
engineering. Within the five aspirations for the profession, civil engineers are to become master “...innovators and integrators of ideas and technology across the public, private, and academic sectors...” (ASCE 2007). Integration is important because projects will be completed with more team members and address complex goals including sustainable issues. Technological advancements will not only provide the tools needed to integrate data, they will allow information to flow among team members. Ralph R. Peterson, a keynote speaker at the 2006 Vision summit, suggested that “Stakeholder communication and collaboration will be as important as technical content” (ASCE 2007). For ASCE, integration includes leadership, technology, a free-exchange of ideas, and big picture thinking.

Coordination and communication are also themes of ASCE’s Quality in the constructed project. From the ASCE Manuals and Reports on Engineer Practice Series, this book promotes honest and open communication as well as a “common understanding of each team’s requirement” (ASCE 2012). Project delivery methods are described, and, although this book was published in 2012, integrated project delivery (IPD) is not included and BIM is mentioned as a tool under development. It is in the section on the project discipline leader (10.4) that integration is identified and described as a benefit to the owner. The “degree of coordination and integration of necessary disciplines” is one aspect of design quality.

A similar resource is the Civil engineer’s handbook of professional practice (Hansen and Zenobia 2011). Here, however, there is more of a focus on emerging technology and practice models. Integration is linked directly to the AIA’s Integrated project delivery (AIA 2007). The handbook also raises the importance of collaborative design, which is described as involving many stakeholders. Concepts of team structure, design methods, project information, and delivery methods also are addressed. Overall, integration and collaboration are two terms that are given importance by ASCE via their inclusion in documents that set out expectations for the field and the practitioner.

**SEI**

A search through the SEI’s major documents and publications revealed limited focus on integration. A joint SEI/Council of American Structural Engineers (CASE) committee exists on BIM “...to explore, document, and disseminate the benefits, risks, and practical and contractual implications of implementing building information modeling, as it affects the structural engineering profession” (SEI 2012). A white paper by the committee examines what digital practices mean to the structural engineer of record and the legal challenges that come with embracing this relatively new technology in both traditional methods and IPD (SEI 2011). Detailed information is provided for the structural engineer in understanding levels of development, and the need for creating a BIM execution plan is expressed. The paper also briefly mentions coordination and prevention of clashes, but there are no other suggestions of integration or acknowledgment of the integration potential of this digital tool.

A second source of information on integration comes from a chapter of the ASCE/SEI publication Sustainability guidelines for the structural engineer called “Design integration and synergies” (Kestner et al. 2010). Design integration, from the structural engineer view, is a mechanism within the project to solve problems proactively and the inclusion of all team members in the development of the concept. Building elements and conceptual ideas are to expand beyond their discipline boundaries to serve the entirety of the project and become part of a sustainable solution. To this end, the chapter outlines areas of sustainable design integration including building form and enclosure. This approach to sustainable design and the guidance on BIM appear to encapsulate SEI’s current efforts toward integration.

**AEI**

AEI was founded based on the concept of integration and has addressed it through education, publications, and recognition of integrated work. At its 10th anniversary in 2008, an editorial of the Journal of Architectural Engineering put forth that “the AEI promotes an integrated, multidisciplinary approach to the design, construction, and operation of buildings, whereby engineers of various disciplines can unite, interact, and share knowledge in an effort to advance the state of the building industry” (Rielly 2008). This idea is also included in AEI’s bylaws as a key objective: “...to integrate the technical and professional activities of all individuals engaged in the building industry...” (AEI 2012).

Authors who contribute to both the journal and proceedings of the AEI tackle the subject in various ways. For example, design decision making is investigated through software development constructed to assist with prioritizing, value appropriation, and timing of such decisions (Mokhtar et al. 2000). The Institute’s conference proceedings provide case studies of building systems integration that examine the design of a laboratory, a medical school, and tall buildings (Bacall and Thomson 2006; Leslie and Dong 2003; Ali and Armstrong 2006). The projects examined assist in refining the understanding of components and concepts of building system integration.

In addition, AEI has worked to define architectural engineering education by enhancing the ABET Criteria for Architectural Engineering Programs. While not specifically calling it integration, the desired outcome, similar to the eventual professional work of an architectural engineer, is about integrating several complex components together. Beginning with the 2011–2012 criteria, the term design is defined to include characteristics such as the following: (1) consideration of multiple systems, (2) architectural design, (3) teamwork, (4) use of contemporary tools, and (5) building performance (AEI 2010). In a 2010 commentary prepared to accompany the changes, emphasis was placed on the curriculum requirements to provide needed knowledge and the skills required to contribute in a collaborative team environment and function on a multidisciplinary team [Criterion 3(d)] (ABET 2012). These enhancements to the ABET criteria institutionalize integration as a goal.

Launched in 2013, the Architectural Engineering Professional Project Award uses collaboration and integration as key factors on which the project is judged in addition to components such as structural and mechanical designs. As the announcement documents stated, “The program seeks to educate students and professionals through examples that illustrate the application of academic studies to practice with focus on the art and science of an integrated approach to architectural engineering” (AEI 2013). The winners serve as case studies to demonstrate successful system integration. This award as well as the ABET criteria enforce the overall intent of AEI to raise the profile of integration within the industry.

**ASHRAE**

For ASHRAE, integrated design and integrated systems are components of sustainable engineering and included in the priorities of the organization. This connection can be seen in the ASHRAE 2011–12 Annual Report (ASHRAE 2012), “ASHRAE strategic plan” (ASHRAE 2011a), and “ASHRAE vision 2020” report that outlines the goals of net zero energy buildings (ASHRAE 2008). The Vision report describes both the need for integrated systems (technical...
coordination of multiple energy systems) and integrated design (“integrate building form and fabric as part of the heating, cooling, and lighting system”) (ASHRAE 2008). Not only does ASHRAE want its members to practice integration, but also it seeks to shape and define what integration practice means. Strategies include “working with others” and “lead the development of integrated design, construction, and operations” (ASHRAE 2011a). Notably, ASHRAE has taken a multipronged approach to meeting these goals and there is a wealth of information on integration available, including web resources, a technical committee, and design guides.

The ASHRAE wiki, maintained by ASHRAE, creates and collects professional terminology, and has approximately 7,600 terms in place that relate to terms found in practice and the standards (ASHRAE 2013a). Here, the term integrated system is defined as follows:

- System in which many subsystems of a building are combined into a single package, e.g., fire, security, clock, and HVAC; and
- More than one building system, such as lights and air distribution, combined into a common design.

Systems, at a variety of levels, come together or are united with intent to form a single entity. This portion of integration is clearly delineated here.

Among ASHRAE’s technical committees is TC7.1 Integrated Building Design. The purpose of the committee is “...facilitating interaction among all building disciplines” with the goal of designing total buildings (ASHRAE 2013c). The major effort of the committee can be found in a chapter of the 2011 ASHRAE handbook entitled “Integrated building design” (ASHRAE 2011b). It includes an overview of project delivery methods and highlights what this process brings, how it differs from a traditional process, and describes the expected outcomes. The chapter goes on to identify objectives of the process, with a special focus on topics important to mechanical engineers such as energy usage and indoor environment quality. Integrated design tools are identified and the role of the owner is outlined. Collaboration is seen as a subset of integrated building design and the subject is further elaborated into the areas of teamwork, team formation, decision making, and team strategy. The chapter identifies specific design tasks and provides a good encapsulation of the subject.

ASHRAE periodicals also address integration. High performing buildings includes case studies like “Green on a budget,” where the design decisions that formed the studied building are illustrated (Nicklas 2008). Other articles include “Building for the future: Integrated design for sustainable buildings,” which argues for the benefits of early design collaboration, diagrams work flow and team roles, and links the process to ASHRAE members’ roles (Lewis 2004). There are also articles that go beyond the discussion of the process of integration to the application of a specific system to demonstrate the evolution of the idea in practice, such as using underfloor air-distribution systems (Montanya et al. 2009).

Design guides by ASHRAE focus on a particular type of building and respond to the unique demands of these buildings. Within the series, there are chapters addressing integrated building design. In the Advanced energy design guide for medium to big box retail buildings: Achieving 50% energy savings toward a net zero energy building, the topic is defined and includes case studies and particular approaches for designing that type of building (ASHRAE and IESNA 2011). Project goals, strategies, and best practices for integrated building design are articulated here as well. The guides provide specific application of the integrated process for specific classes of buildings.

Rounding out ASHRAE’s resources on integration is a class, “Professional development seminar: Integrated building design” (ASHRAE 2013b). Its description states, “Emphasis will be placed on transitioning traditional processes that aggregate isolated silos of knowledge into collaborative thought and shared outcome” (ASHRAE 2013b). ASHRAE also makes available a 3-h training video called “Integrated Building Design: Bringing the Pieces Together to Unleash the Power of Teamwork.” Altogether, ASHRAE has addressed the topic of integration from basic levels of understanding and transformed the knowledge into detailed information that can move the practitioner from novice to integrated designer.

AIA

AIA has been proactive in addressing integration through efforts such as the Center for Integrated Practice (CIP) (AIA 2012a) and the launching of IPD (AIA 2007). In addition, the organization provides resources to address the impact of BIM and considers the basic practice of integration in its handbook. The CIP is an online resource that compiles information on integrated work and its goal is “to lead the industry toward collaborative design practices” (AIA 2012a). The CIP 2006 Report on integrated practice is a compilation of papers that set out “...to frame the issue and provoke your thoughts on how project delivery must change to better meet the needs of our clients and society” (Broshar et al. 2006). BIM is a theme that is addressed as a design tool, a factor in business models, and as necessary for implementation of integrative work. Among CIP’s undertakings was returning to the Report on integrated practice in 2009 and expanding or reevaluating the topics in a new series of essays and podcasts.

The 2007 IPD method aims to remove practitioners from a project framework that prevents cooperation from occurring and replace it with a process based on principles of mutual respect and openness in contractual relationships (AIA 2007). The progress of this project delivery system has been studied in “Integrated project delivery: Case studies” (AIA 2010) and “IPD: Case studies” (AIA 2012b). To complement the project delivery method, the organization also has created contracts to aid in its implementation. There are three groups of contracts to coincide with three degrees of IPD as follows: (1) transitional, (2) multiparty, and (3) single-purpose entity, in order of the extent of implementation. Contracts for the first step of IPD include A195–2008 (owner and contractor) and B195–2008 (owner and architect). Consultants are engaged through the normative C401–2007 document (AIA 2013c).

The contracts integrate owner, architect, and contractor and mandate the use of BIM. Coordination is stipulated (including staged agreements between the architect and contractor) and environmentally responsible design alternatives shall be considered (AIA 2008c). Some concrete steps toward integration are contained in this transition document, but hierarchies such as existing relationships with the architect and their consultants remain embedded. The other end of the IPD spectrum is the single-purpose entity (SPE), whereby a limited liability company is created for a project. The SPE creates a practice environment with shared risks and rewards. It is constructing an unconventional framework in which integration is the preferred way for the team to practice. Multiple contracts tie into the framework document C195–2008 (SPE for IPD). One important piece of C195 is Exhibit DD: Integrated Scope of Service, which is a detailed matrix allocating tasks. The SPE approach has not been wholeheartedly accepted by the field as few projects are using such contracts (AIA 2013a).

Part of the transformation to IPD includes the embracing of BIM. The use of this relatively new technology has created areas of uncertainty, especially when it comes to liability and ownership of such data. To aid the practitioner, the AIA developed “Building information modeling protocol exhibit” (AIA 2008b). The document provides detailed language, the ability to recognize levels of work, and
decision points for model methods or formats. This document was superseded in June 2013 with the launch of AIA Digital Data Practice Documents, including document E202-2013 “Building information modeling and digital data exhibit” (AIA 2013b). These documents are meant to capture the evolution in digital practices and meet current needs. The AIA’s Guide, instructions and commentary to the 2013 AIA digital practice documents (AIA 2013d) walks the practitioner through each document and its intentions. This endeavor by the AIA is recent and has not yet been significantly used in practice.

The architect’s handbook of professional practice (AIA 2008a) articulates the fundamentals of integrated practice. The teamwork approach is emphasized and the roles are expanded; each design phase is examined and design tasks are outlined for those stages. This process is described as follows: “At the core of an integrated practice are fully collaborative, highly integrated, and productive teams composed of all project life-cycle stakeholders” (AIA 2008a). The brief section also touches on technology and the legal issues that are involved. The AIA’s integrated design appears to follow in the footsteps of ASHRAE, and the methodology is intertwined with the production of a sustainable building.

As with engineering, architecture has a series of accreditation requirements for architectural education. Collaboration, building systems integration, and comprehensive design can be identified in the National Architectural Accrediting Board (NAAB 1998) criteria. Since that time, the criteria language of collaboration and integration has strengthened and gotten more specific. Collaboration moved from “to cooperate with other students when working as members of a design team” to the “ability to work in collaboration with others and in multidisciplinary teams to successfully complete design projects” (NAAB 1998, 2009). In 2009 there was a reorganization of the criteria that placed an emphasis on integration with formulation of “Realm B: Integrated Building Practices, Technical Skills and Knowledge.” It is in this section that comprehensive design, technical skills, and sustainability come together. While not under the purview of the AIA, the intention of integration can be found in the requirements for the education of an architect. For AIA, a new project delivery method, BIM, and teamwork are essential to integration, and it is working to ensure that practice changes to incorporate these components.

AGC

AGC addresses integration through its efforts to embrace BIM and IPD. In its 2006 Annual Report (AGC 2006a), BIM was seen as an educational mandate for the group’s members. Not only was the technical information important, but members needed to understand its potential “…including the possibilities for improved productivity and unprecedented collaboration” (AGC 2006a). In the same year, AGC and AIA hosted a summit to examine the impact of BIM on a project, the process, and the industry. Then-president of the organization, Harry Mashburn, recognized that “[Early collaboration] means establishing a new type of relationship among all parties involved in a project” (Shaw 2006).

From the development of the AGC’s Contractors’ guide to BIM in 2006 (AGC 2006b) to the four-unit BIM Education Program of the AGC (AGC 2013) and the Certificate of Management–Building Information Modeling in 2010 (AGC 2013), the organization has found value in the digital tool. The technology is seen to allow for better unification of teams, information, and the final project. For his year as AGC president, Mashburn indicated that an initiative on integration was important for its members: “We want owners to look to the construction industry, and specifically, contractors, as professionals who are a vital part of the whole process, not just a commodity” (Shaw 2006).

To aid the transition to BIM for its members, the AGC created and launched ConsensusDocs 301 BIM Addendum in 2008 (ConsensusDocs 2012). The document, as expressed by the AGC, is able to be used with traditional contracts and preserves the boundaries between designer and contractor. Included in the addendum is a “BIM Execution Plan,” acknowledgments of levels of reliability of the models, and efforts to resolve model ownership—an issue whose resolution still is being determined within the A/E/C community. BIM, the change it created in the work processes, and the more united work it produced were seen as increasing the impact of the general contractor as a profession.

In the AGC report Integrated project delivery for public and private owners [National Association of State Facilities Administrators (NASFA) et al. 2010], a structure to integration is provided. Collaboration is classified into three levels and IPD can be applied as a philosophy or delivery method. Each level of distinction is interpreted as a level of commitment to integration with Collaboration Level 1 and IPD philosophy being linked to traditional practice and with levels of investment increasing in each from here. Full integration occurs when collaboration is contracted and IPD “fully integrates project teams to take advantage of all team members to maximize the project outcome” (NASFA et al. 2010). The organization recognizes that integration can occur on any of the three levels, but has remarked in this report that Level 3 has produced remarkable results owing to team members having aligned goals and an interest in collaboration. Like the AIA, the AGC identified integration as beneficial to improving the industry and their profession. Their work to embrace IPD and BIM are concrete actions to implement it.

State of Integration

These organizations, four engineering, one architectural, and one contractor, were studied because of their influence on their fields. Not only does their work reflect the status of the professions, but they also have direct impact on the state of practice. Examined individually, each organization has made progress in the last 10 years toward a more integrated practice. However, the A/E/C community is not unified in its understanding or implementation of integration and significant variations remain. For instance, AIA defines integration as “the coming together of primary participants” (which could include owner, designer, constructor, design consultants, and trade contractors, key systems suppliers, etc.) “at the beginning of a project, for the purpose of designing and constructing the project together as a team” (AIA 2007), while AGC notes that the term is used not only broadly but interchangeably with collaboration (NASFA et al. 2010). The variance in the use and lack of specificity makes that aspiration difficult to achieve.

The two contributing elements in this push toward integration are BIM and IPD. All the national organizations here have demonstrated a commitment to using BIM, and have addressed its inclusion with AIA and AGC defining how it is used in the structure of a project through their contracts. For IPD, AIA is promoting the potential of the delivery method and AGC is supporting its use as a benefit for project owners and its members. Not only does IPD modify the reward structure of a project but it also changes the risk. This has led to a wait-and-see approach for its full implementation by the field in general. On the other hand, both of these endeavors have the possibility of transforming practice, and their convergence has led to the current environment where the prospect of change is perceptible.

For ASCE, integration is valued through its inclusion in documents that set out future expectations for the field, with the idea that engineers will need to be master innovators and integrators. Its acknowledgment of the importance of integration is significant—it places the engineer as a critical member of the design team and adds
the expectation of these abilities on its members. Few details or specifics are provided, and this partially can be attributed to the scope of the organization, which represents the larger field of civil engineering. SEI, where one might expect some guidance for structural engineers, appears to be relatively silent on the matter, but has offered some recognition that integration is important in sustainable design and that the engineer needs support transitioning to BIM.

AEI was founded on integration and multidisciplinary work. It is a priority for the group as it seeks to combine work from related but often separate disciplinary fields. The new annual award recognizing built work that incorporates the highest standards of integrated design offers exemplars for practitioners. Integration, mentioned in the group’s mission and bylaws, is a topic of conferences, conference papers, and journal articles, but the organization has not yet taken steps to guide the larger conversation.

Perhaps the best benchmark for integration is provided by ASHRAE. ASHRAE promotes the idea of integration in its Handbook, design guides, and in a professional development workshop. In addition to strongly reinforcing the importance of integration, ASHRAE provides specifics to members regarding how to break the topic down into achievable pieces. From the guidance provided, it is apparent that the organization is focused on moving the practice methods of building designers into this new level of integration and collaboration. All of these efforts assist ASHRAE toward its goals of energy efficiency and sustainable buildings.

AIA addresses, defines, and finds importance in integration. Integration is seen as benefitting the process and the end result. AIA’s role is appropriate given that architects are historical leaders of projects and coordinate the goals of the owner with the work of the design team members. Resources available to the practitioner include contracts for IPD, an information resource center, IPD guide, and digital practice documents.

AGC approaches integration in order to transform, not only their professional standing, but how they work. The organization provides guidance on IPD and delineates collaboration and integrated projects into levels aligned with the commitment to working in a new structure.

Design team integration was specifically addressed by AIA, ASHRAE, and AGC. The team is to be organized early, more inclusive than a traditional-practice team, and have jointly defined goals that are written into a contract. Some of the main parameters of AIA’s IPD is that “key participants are bound together as equals,” and share a “willingness to collaborate” (AIA 2007). For integrated building systems, AEI and ASHRAE stand out as embracing this specialization. As building systems are primary foci of these organizations, it is a natural fit. Integrated design information is a theme for each group. An integrated building, or the final product, is the goal of ASHRAE and AIA, though this is implied for the other groups. Integration is developing processes to get to a better building for the owner and the environment. The prioritization of integration, therefore, very much depends on each group’s perceived goals, and not every organization has yet fully embraced the topic.

Conclusion

Integration remains one of the big issues of today. In the mid-2013 AIA foresight report, integration is seen as a directive that will change roles, design, construction, and education (AIA 2013a). The need for integration will change practice, and the AIA is signaling this to its membership. Nevertheless, the question of how to create a more integrative environment remains unanswered. This survey of the resources and publications from the national professional organizations indicates that it is important to the industry on the whole, but that the effort to include integration into the A/E/C industry varies in commitment by discipline.

There has been much progress made in the last 10 years in defining the various subsets of integration. This is in part because of the desire to change business practices, specific organized efforts by some of the organizations, and the development of tools to help integration occur. ASCE recognizes the change in the field, but has not provided much further guidance. SEI is cautious to approach this nontechnical subject and may find itself far behind. AEI, a natural home for integration, has some good endeavors, but is far from sharing its knowledge in a leadership capacity. ASHRAE works to describe, implement, and evolve integration and its success is noteworthy. AIA is attempting to lead and structure integration. AGC sees integration, and not incorrectly, as a way to provide value to a project and for their profession. While there is unevenness in the industry toward integration, there is movement to address the complex idea and changes are ongoing. However, further work is still needed to define or continue to redefine integration within each field and as a community.