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Systemic Framework for Planning of Construction Education for the Next Generation in the United States.

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Abstract:

Construction work that will take place in the United States in the next few decades will be fundamentally different from the type of construction work that has been typical in the last few decades. The titles of the traditional construction and construction management undertakings in terms of design, estimating, costing, bidding, specifying, scheduling, construction, contract administration, inspecting, safety, etc., will not change. But, profound changes will occur in the nature of the work done within the context of each of the above undertakings, paralleling the changing nature of construction work, construction technologies, the nature of the labor force, impact on the environment, advances in computer technologies, monetary size of the construction undertakings, and security issues. This paper focuses on detailing what changes are to be expected in the nature and technologies of future construction work and what the appropriate response will need to be in design of construction education curriculum, coursework, and lab undertakings to ensure proper preparation of graduates for the construction works of the next generation.

Introduction

Even though this paper will deal mainly with what will characterize the future of construction work, it is important to note what kind of developments influenced construction work in the near past. The main factors that were drivers of change in construction undertakings in the past several decades included:

- New materials (high strength concrete, composite materials, carbon fibers, etc.)
- New building methods and delivery systems (partnering, open building, fast tracking, etc.)
- New methodologies for planning and tracking on-site productivity (management information systems applied to construction industry, etc.)
- New regulations for construction work (safety, health, environment impact, etc.)
- New communication technologies (internet, email, cellular phones, etc.)

The following part of the paper will focus on what will characterize construction work in the coming decades in the author's opinion and what this will mean for construction education. It is to be noted that this coverage below is not in any order of priority.

Changing Nature of Construction Work and Expectations

Changing nature of construction work will be addressed in basically six categories as detailed below, with the characteristics foreseen for each category described briefly for clarification purposes.

1. ***Increasing difficulty in finding qualified construction trades labor:*** no matter how much the profile and characteristics of construction work have improved, the perception of construction as a rough and tough industry remains the same and continues to negatively affect the recruitment into the industry. This will necessitate that the construction trades labor and possibly some management shortage be replenished by a workforce from abroad or opting for construction technologies that use less labor and more technology and equipment/machinery.

   The former necessitates that construction education also focus on human behavior of diverse people in the construction industry from different cultures and backgrounds to prevent conflicts, failures, and jeopardizing of safety. Tithius and Fellow [31] emphasize the need to be aware of the relationship between culture, project organization and technology within the context of a management tool that integrates contact, contract, and conflict. Control of the interrelationships between different cultures involved in a construction project becomes very important since differences in function and conduct of different parties can lead to conflicts.

   So not only is it important that we get our students used to working in teams themselves but also learn to set up proper project teams being cognizant of inherent differences in human behavior due to cultural, ethnic, religious, national, and other backgrounds.

   The above issue is also important because of the reality that over time the U.S will probably have to export more construction expertise, consulting, and construction services to balance the information technology, manufacturing, and other jobs going overseas. This will require construction managers, our students of today, to understand the foreign construction techniques, delivery systems, operations, as well as, the foreign cultures and resultant inherent differences in thinking and behavior.

   In terms of the issue of decreasing the demand for the construction workforce, some of the possible venues are industrialized construction, increased use of robotics and mechanical means and other similar approaches. This essentially means looking at construction work more and more as a manufacturing activity and trying to make it even more so. This necessitates that students need to know more about pre-cast concrete construction, increasing use of mechanical connectors in construction, robotics in construction, modular construction to enable increased industrialization, engineered and pre-manufactured construction products [24].

2. ***Stage and inventory of some construction work in the nation:*** the best example to this is infrastructural construction. The federal and state highway and bridge construction has reached a point that new additions to the present inventory will be marginal. The highway networks are now complete or close to completion. Highway and bridge construction work related to repair, resurfacing, re-decking, rehabilitation, replacement, and recycling, on the other hand, is expected to be substantial. Of the 600,000 bridges in the nation, a growing number are deteriorated and as many as 50% are deficient and must be repaired, upgraded or replaced in the near future [31].

   Similarly, even though new sewer and storm-water drainage construction will continue at a slow but steady pace, together with construction-related to separation of combined sewers, major construction work is expected to occur in relining, rehabilitating, and repairing of the sewer/storm-water infrastructure. In addition, due to ever increasing demand for national and global communication, construction related to using the sewer/storm line pipe inventory for conveyance of communication and other types of utility lines, especially in the metropolitan areas, will be a new and increasingly recognizable construction activity. For instance, main fiber artery installations have reached peripheries of all major cities but need the sewer lines for final connection to buildings. This will lead to special construction and installation work in the sewers [16].

   The nature of the sewer/storm-water construction is also changing in terms of the techniques used. An example is the cut-and-cover methodology for installing utilities in trenches such as water, gas, sewer, etc, which is still being used, but is increasingly unfavorable in the opinion of both the public and businesses compared to competing more non-invasive and non-disturbing "trenchless construction" technologies. Not all of the above topics/issues are mainstream materials we include in our traditional curriculum and cover in our classes. We need to have a stronger emphasis on repair, replacement, rehabilitation, recycling, and the like for all kinds of infrastructural construction work, as well as, courses or parts of courses dealing with totally new technologies in diverse utility constructions, including but not limited to various methods of trenchless construction.

   Trenchless technologies both in terms of new underground infrastructure, as well as, repair and replacement of existing underground infrastructure, necessitates that in addition to our traditional above ground surveying emphasis, we also begin to address what may be called the underground surveying issues. This mainly deals with the methodologies and equipment related to location of underground infrastructure, a field of increasing complexity especially in construction in the urban environment.

   Water industry construction also needs to be considered in this category. In line with increasing hygienic and comfort expectations in our lives, this type of construction that encompasses sewer, storm water, water, wastewater, and drinking water construction is estimated to thrive at a steady pace together with its ancillary construction related to filtration, water storage, tanks, pumping stations and systems, piping networks, construction related to security of water related construction and the like. This construction will be driven by the need to separate the combined sewer and storm water lines, enhance the quality of storm water and sewer treatment, and more stringent water quality standards that will lead to upgrading of a number of existing systems, as well as, construction of new ones. Lateral construction in relation to final connection of buildings to main lines of different kinds will also be significant. This type of construction is also increasingly affected by environmental impact considerations.

Water industry construction will increasingly necessitate that we equip our graduates with the fundamentals of environmental engineering knowledge, as well as, with the increasingly challenging financing, legal, and political framework aspects related to such work.

3. ***Increased emphasis on "green" products for construction, sustainability issues, and impact on the environment:*** it is increasingly the case that the construction industry is being expected to be more accountable in above respects. There is a slow but steady movement towards "green" design and construction where special emphasis is attributed to energy used in production of construction/building materials, energy used by buildings within the context of their design and construction, as well as, in operation of their HVAC and water/wastewater systems. Recyclability of materials used in construction and use of recycled products construction are also very current and popular issues. Systems are in place in terms of assessing products of construction work in relation to their sustainability, longevity, and impact on the environment [4,17,32].

   Traditional concepts in relation to feasibility, constructability, construction financing, structure-construction interaction will also change influenced by the growing emphasis on use of "green" materials for minimal negative environmental impact. Use of life-cycle costing for justifying and financing construction, use of information technologies to facilitate and enhance integration of structural designs and construction methods, and use of information flow for construction management and training will increasingly be the norm.

   Most often these issues are coupled with life-cycle assessments of constructed works in terms of meaningful tradeoffs between "design and construction costs" and "operating and ownership costs." A life-cycle analysis is often necessary to include life-cycle economy, environmental impact, design and construction for re-use, rehabilitation, recycle ability, and easy repair considerations. These considerations have brought to the forefront the use of artificial aggregates, recycling, using waste from other industries, using fly ash in artificial aggregate production and in concrete, using recycled aggregate concrete for structural purposes as very relevant construction issues [2,13,15,28].

   The above indicate to real need for revamping our "construction operations" and "construction and engineering economy" classes. Construction operation classes need to go more into recycling of construction materials in terms of their choice and use, as well as, construction techniques that will facilitate easy maintenance, remodeling, re-use, rehabilitation, repair in the long term.

   Construction/engineering economy classes need to go more into life cycle assessment, construction financing, and private-public collaboration issues in view of enormity of pending construction work not rendering itself being very conducive to execution in terms of practices that have characterized such work in the past in terms of justification and feasibility, financing, delivery systems, and public-private collaborations.

Again, even though these topic are not mainstream topics in a typical curriculum, courses related to green design and sustainability issues need to make inroads into construction curricula.

4. ***Construction as a big investment:*** ever increasing realization that construction is a big investment and its long-time survival and being fully functional throughout its lifetime or for a long time carries a lot more weight than it ever did. It is no longer enough that construction be technically realizable (i.e. constructability issues), inexpensive, safe, generally satisfying in terms of human comfort, aesthetical and ecologically appropriate. Issues related to the HVAC energy use, heat loss and gain, lighting, energy use for production of construction materials used, water and wastewater services are also in the picture.

   In line with above, it is obvious that the main theme of constructability, which is covered to some degree in most curricula, is still very important but so is the repairability, maintainability, ease of repair and remodeling and rehabilitation. Normally, designers do not receive much feedback from people involved with construction and related aspects as stated above, or from facility managers for that matter, after designing a building according to owners' wishes. However, this whole picture is due for a total makeover in view of the need to look at construction work of the future as a manufacturing activity necessitating a close collaboration between owners, designers, facility managers, construction, maintenance, repair and remodeling people for obvious reasons, as is now the case when manufacturing a car. Any type of construction is in most cases a more significant investment than any other kind of investment we make in manufactured products in our daily lives and this collaboration is a requisite for long term returns from the original investment rather than total destruction and new construction to suit the future needs [8,11,21].

   Our students, as future decision makers in this framework, need to be aware of more than constructability, partnering for long-term survival and usefulness of any type of construction. Our sincere efforts to instill a collaborative culture in our students, without stifling their individual creativity and innovation, carries great importance [6,20,33]. Within the same above theme, competency in risk management concepts is increasingly important for our students [9,29].

   Combining the non-building type of construction work to residential and non-residential construction, it is expected that all construction work will average about $ 870 billion annually for 2003, 2004, and 2005 in the U.S. It is estimated that of the average of about $ 420 billion to be spent annually in residential construction in 2003, 2004, and 2005, an average of about $ 125 billion annually will be for improvements rather than for new construction. Similarly, it is estimated that of the $ 275 billion annual construction in non-residential buildings, about $ 90 billion will be for improvements [19].

5. ***Earthquake and national disaster resistant construction:*** It is increasingly clear that more areas in the U.S. are earthquake prone than originally assumed or thought. Given also the fact that there is no shortage of hurricanes and tornados and lately possible terrorist acts that may hit the nation at various locations with some frequency, response of construction practices to such incidences will be inevitable. The fact that after every such incidence so much is written about what could have been done in original design and construction to mitigate the consequences will eventually register or should register as issues that will characterize future construction work.

   It is most often the case that some simple awareness of proper construction details that will respond appropriately to such disasters is ignored in our traditional curricula and needs a revitalized focus. A case in point is earthquake resistant construction details developed for wood-frame residential construction, which also will serve us splendidly against tornados, hurricanes or other high wind situations. These are simple improvements that involve simple connection gear and practices that, in my personal opinion, all of our students need to know through adequate coverage in relevant courses.

   Along the same realm, type of construction titled "strengthening," is increasingly becoming important and will continue to do so. This is not only due to the efforts to bring structures in earthquake and other disaster prone areas to current standards but a natural outcome of dealing with an aging construction, infrastructural or otherwise [3,7,14,18,23].

   This necessitates a focus in our curricula not only on the construction operation of strengthening but also a focus on a myriad of new materials making this possible such as the CFRP laminates [23].

   Blast-resistant design and defensive design are terminologies that are increasingly being used in the structural design arena and it would be no surprise that blast-resistant construction and defensive construction will soon follow suit.

6. ***Computers and information systems technology:*** There is no doubt that computers and related information systems/technology has influenced construction work and its execution in various ways and will continue to do so [30]. Use of 2-D CAD, 3-D CAD, project execution related communication work using the internet, use of project management information systems, use of internet-based training/learning is increasingly becoming mainstream. As far as new entries go, 4-D CAD systems that incorporate the time element into 3-D CAD work is making great strides in terms of showing proper construction sequencing in parallel with 3-D drawings, greatly facilitating construction operations especially in view of a construction workforce whose training is not keeping pace with the advances in construction work technology [1,5,26]. Similarly, database-assisted design and construction that rely on real database values and statistics (e.g. extreme wind resistant construction) are providing opportunities for more relevant and optimal design and construction undertakings [12].

All this is indicating to a need to define the minimums in terms of computer and software use in our curriculum so that we equip our graduates at least with fundamentals for them to be able to build on it for what will be coming in future's construction undertakings. In my opinion the minimal platform at this point needs to be 3-D CAD, estimating and bidding software (Timberline, Heavybid, etc.), scheduling software (Primavera, etc.), construction administration software (Prolog, Expedition, etc.), hydraulics drainage software, (Haested methods software TR-55, TR-20, etc.), with appropriate and timely ventures into 4-D CAD, rapid prototyping for construction, and database-assisted design/construction as resources allow.

What are we doing ?

Even though this paper inherently conveys the message that we at the Department of Construction Technology at Purdue School of Engineering and Technology at IUPUI are aware of characteristics that will define future construction work, it does not necessarily mean that we have been able to respond satisfactorily to all the issues described above.

We are aware that the more flexible ABET criteria of today allows us to respond to the characteristics of expected future construction more easily than ever before. Still, there is the well-known difficulty of trying to decide on what to take out from the old curriculum to put in the new. Human nature is that we all think what we cover is just the basic fundamentals and that there is really nothing to take out. While we still continue to struggle with this, we would like to think that we have made some headway as follows:

- We have dedicated courses and undertakings that deal with: the "green" design/construction and sustainability issues, electives that deal with energy considerations for construction work from the environmental impact perspective.
- We have offered courses related to the whole area of trenchless technologies.
- Our construction and engineering economy course is planned to deal more with life-cycle costing and construction financing issues.
- We are revamping our list of acceptable humanities/social science and lab science electives to enhance the chances of students being exposed to diversity and other contemporary issues as elaborated on above.
- We have new topics as emphasized above making their way into our construction materials, systems and construction operations classes so that we cover composite materials, CFRP laminates, etc.
- We have enough use of the software that has proved to be of essential for construction graduates to build upon further in their respective careers in the future.

Is what we are doing an adequate response to the expectations? Probably not, but given the inherent resistance to change and comfort associated with the traditional, it is to be expected that the pace of change will be slow. To name a few items, we are still lacking adequate coverage for:

- Environmental issues and basic environmental engineering concepts.
- Being able to enter the 4-D CAD area and its implementation.

- Underground surveying and the technology and equipment involved in this field.
- Earthquake resistant, blast resistant, tornado resistant, hurricane resistant, defensive type of construction concepts and the inherent details.
- Pre-cast and modular construction and related equipment and construction details.
- Robotics in construction and mechanization of construction operations to facilitate application of manufacturing concepts and methodologies.
- Construction details to ensure long-term flexibility for repair and remodeling for changing uses or needs over the life-cycle of construction work.
- Concepts of diversity as it relates to construction and the composition of its future workforce.

Conclusion

This paper hopes to bring forward some of the issues that will characterize future construction and how we can satisfactorily respond to changing profile of construction work for the foreseeable future. It is by no means meant to be exhaustive in terms of anticipating or extrapolating all the possible changes in the construction industry, nor does it intend to bring a solution or response to all the expectations. However, there is no doubt that future construction work will be quite different from what has characterized construction work in the past in several respects and that we need to be cognizant of what may be coming so that we respond to the expectations in due time in terms of graduating the construction engineering and management graduates of the future. Expected changes in construction work put an onerous responsibility on construction educators, administrators, advisory boards, and other entities involved with curriculum design, development, and integration to think about the future of construction work and new construction technologies and chart an active path. No longer can we passively react to what is transpiring. Construction education must be modified appropriately to respond to impending changes in a timely manner. It is my hope that this paper will stimulate even further and better thinking than I have been able to bring forward about the topics raised and create an inertia for movement in the right direction.

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Biography

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