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A Framework for Managing Building Construction Technology for the Campus Owner through a Building Design Sustainability Safety and Maintainability Assessment System

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Abstract. The design of modern buildings must account for constructability, buildability, sustainability safety and maintainability. At present, these concepts are tracked and applied in an uncoordinated way and the resulting missed opportunity for increased resource usage is not realized. The research proposes a framework for a coordinated application of these concepts for the campus owner.

Keywords: Constructability, Buildability, Sustainability, maintainability, Safety.

1 Introduction

Being more efficient and wise with resources, sustainability is vital to life and the environment. Sustainability has crept into evert facet of modern life including building design and construction. The proliferation and maturation of sustainable building rating systems demonstrates the acceptance of sustainable design and construction. In addition to rating systems for sustainability, rating systems to gauge the constructability and buildability of completed designs are also in use around the world. Considering the concepts of sustainability (Su), constructability (Co) and buildability (B) in the design and construction phases may lead to successfully delivering a building to an owner, but the success of a construction project does not conclude at the end of construction or owner occupancy. Maintenance of a building is required for the building to operate as designed and at its optimal performance. The ease of maintenance throughout the life of the facility must be an element considered when determining the success of a project. In other words, the project must be maintainable. A further aspect of a maintainable design is the design must be safe to maintain

When a single owner has many facilities of the same or different building types, the buildings establish a campus for that owner. For the campus owner, the importance of a consistent application of Co, B, Su maintainability (M), and safety (Sa) in design cannot be overstated. The impacts of these design and construction decisions can be significant for the individual building. However, for the campus owner, they are multiplied many fold. A small savings is construction cost or maintenance down time multiplied over many buildings can result in great savings in time and resources. The campus owner needs a structured framework for the application and tracking of these independent and synergistic concepts in the design, construction and maintenance of their completed projects. Through the use of subject matter expert (SME) focus groups and an online survey of designers, constructors, authorities having jurisdiction (AHJ), and campus owner's representatives, this research will delineate a framework for use in the design process that could provide structure to the consideration of the relationship between these separate concepts.

2 Target Population and SME's

The target campus owner for this research is the State University and Community College system in the southeastern US. Each campus includes many buildings and many different building types. Buildings as diverse as student centers, dormitories, laboratories, classroom buildings, dining halls, recreational facilities, sports facilities, energy plants and maintenance facilities could all be on the same campus including multiple buildings of one type. Each of these facilities must have a designer, constructor, operation staff, and maintenance staff in addition to the intended building users and operating departments. The SMEs will be architects, licensed contractors, campus owner personnel (project managers, facility managers and maintenance workers) and AHJ's.

3 Discussion

The owner of a facility is required to provide a safe work environment as enumerated in the Occupations Health Act of 1970. State governments are exempt from the rules and regulations of the OSH Act, however, they must create and submit a plan specific for the jurisdiction and obtain approval on how they are to provide the protections afforded by the Act. In addition, the universities included in this research have maintenance workers on staff. As these maintenance workers are part of the normal work force, they are expected occupants of the completed facility. Addressing their Sa within the work environment during the design phase of buildings is required.

Prevention through Design (PtD) is an initiative from the National Institute for Occupational Safety and Health (NIOSH) and is defined as encompassing "all of the efforts to anticipate and design out hazards to workers in facilities, work methods and operations, processes, equipment, tools, products, new technologies, and the organization of work." The focus of PtD is on workers who execute the designs or have to work with the products of the design. The initiative has been developed to support designing out hazards, the most reliable and effective type of prevention [1]."

The idea of reviewing the role of designers in PtD arose in 1990, aimed at the Sa of the construction worker. The design community (architects and engineers) resisted being involved in construction Sa with many designers commenting that legal counsel had specifically advised them not to address Sa in order to avoid the assumption of any liability [2].

The underlying concept establishes the campus owner's requirement by law to provide a safe work place to their employees and that obligation transfers an obligation to the architect. The obligations of the owner encompass the maintenance staff.

The World Commission on Environment and Development [3], was challenged to define "a global agenda for change." In their report, more commonly known as the Brundtland Commission, they created the most widely accepted definition of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Su is a broad concept that encompasses "continuity of economic considerations, resource conservation, and social aspects of human society in addition to the environmental characteristics [4]." To assist building designers to achieve a balance of economic and social needs, designers use Su-rating systems for building design. Behm, Lentz, Heidel and Gambatese [5] argue that a building is not sustainable without being safe to construct. To extend this idea further, a building is not sustainable without being safe to maintain.

Constructability reviews are a good method for introducing construction knowledge into the initial phases of the design process. The Construction Industry Institute defines Co as "the integration of construction knowledge in the design process in an attempt to provide efficient use of resources, increase ease of construction and optimize the project requirements." Many studies [6] [7] [8] [9] [10] [11] have addressed the concept within the design firm since its introduction in the 1970's [12].

The Building and Construction Authority [13] in Singapore provide a definition of B as "the extent to which a design facilitates ease of construction as well as the extent to which the adoption of construction techniques and processes affects the productivity level of building works." "Any principles or philosophies of B must sit within a set of overall requirements for the completed building, which may in some cases be in conflict with the principles of B. This is to say that the overall project goals may actually restrict the B of the project, such the heuristic principles of B may not necessarily be appropriate in all cases [14]." In other words, B must be coordinated with other aspects of building design such as the program, Su and M.

Seeley [15] defines building maintenance as "any work carried out to sustain the building's utility and value by keeping, restoring or improving every building's parts, including its services and surroundings, to an up-to-date standard." An expansion of building maintenance is M. M is a design parameter of the system's 'ability' to be maintained in its effective and efficient state, without adversely affecting the mission of the system. The implications for the design phase are to make adjustments early in the process to minimize cost and effort.

As with any construction project, an AHJ must review the completed design for conformance to buildings codes. "Authorities having jurisdiction (AHJs) include building code officials, zoning officials, inspectors, and regulatory agencies [16]."

Asmone and Chew [17] have explored a multi-criteria assessment system for managing the synergistic relationship between M and Su. The timing of construction knowledge input from the constructor in the Co review is vitally important to the design team. The results of the Co review permit the design team to design, to make adjustments and document a buildable design at the most cost effective manner. The materials selected in the design process will have a great impact on the Co, B, Su, M, and maintenance worker Sa. Chew instructs [18] “M of a building is its ability to perform optimally throughout the lifespan within the minimum life cycle cost.” In other words, minimizing the life cycle costs can be achieved by combining Su and M producing green M. Chew, Conejos and Asmone [19] state “green M occurs with sustainable development strategies and is defined as making maintenance more environmentally benign by ensuring that maintenance has minimal negative impacts while ensuring the protection, health and safety of maintenance personnel.”

The concepts of Co and B are inextricably linked. Using the Building and Construction Authority’s (BDA) definition for B as the accepted definition for Co, it is easy to see that the efficiency and ease of construction optimize resource usage while integrating construction knowledge into the design process. Subsumed within the efficient use of resources are the concepts of Su, M as well as Sa.

At present designers, specifically architects do not address Sa of the maintenance worker. The maintenance of a completed facility is an expected necessity; therefore, the maintenance worker is a normal occupant of the completed facility for the purposes of this research. As such, the inclusion of the Sa requirements for the maintenance worker along with the Co, B, M, and Su aspects of the architectural design process will enhance the effectiveness of each of these aspects.

There is no single tool to document the coordinated application of these separate but synergistic concepts which allows the campus owner to monitor the progress toward the owners set goals for each of these concepts. The building design sustainability safety and maintainability assessment system (BDSSMAS) integrates the separate functions Co, B, Su, M and maintenance worker Sa into one system for the campus owner. At present, tracking each of the concepts is done individually or not at all and misses the opportunities offered by an integrated synergistic process. There are a myriad of benefits from integrating these functions into one process such as; reviewing building design documents and Co review suggestions against the other factors to educate the decision makers of the impact the suggestion has on the required overall score and other factors.

A unifying system for the application, tracking and synergistically managing Co, B, Su, M, and maintenance worker Sa does not exist for the campus owner when designing new construction projects. To address the lack of a unifying system, this research will demonstrate one possible framework for managing the technological synergistic relationship and integration of the five aspects (Co, B, Su, M and Sa) into the design of buildings resulting in more thoughtful and sustainable use of the technology necessary for the design and construction of buildings. The design of buildings must account for technology at an ever-increasing pace according to Moore’s Law and the science of building construction is progressing just as quickly. A framework is required to maintain focus on the different aspects of integrating the technologies of Co, B, Su and Sa maintenance into the completed design.

Model such as the Conceptual Product Process Matrix (CPPMM) model introduces the issue of Co comment timing in to the design process [20]. The CPPMM model determines the appropriate time in the design process to review Co issues based on the particular phase of the design. Incorporated into the CPPMM, is the influence curve.

As defined by Hollmann [21], the influence curve represents “the potential to influence the value of an asset diminishes as asset planning and implementation progress.” In other words, the earlier a decision is made in the design process, the more the potential disruption is lessened. Conversely, the later in the design process a decision is made, the greater the potential for disruption to the project, from either a cost, time or materials usage perspective.

Another method for documenting Co is the buildable score card used in Singapore. This is a method of determining a minimum B rating for a project. The Building Design Appraisal System (BDAS) determines a minimum score for building designs before issuing a building permit [22]. The BDAS is a type of Total Building Performance rating system. “Because each stage in the design process includes decisions that carry forward through the project, changes to previously approved decisions incur additional costs [23]”. Evaluating the Co of the design after it has been completed fails to utilize the lessons of the time-safety influence curve [24]. In addition, changes in the latter stages of design increase the possibility of errors in the documents used for bidding and construction. Pulaski and Horman [20] state there is a demonstrated desire for Co review efforts within the design firms demonstrated by 50% of the design firms having a formal Co review program. Arditi, Elhassan and Toklu [5] report 95.7% of the respondents (designers) are aware of the term Co. In addition to Co, B is another concept best utilized throughout the design process.

4 Proposed BDSSMAS System

The BDSSMAS will utilize a point system to reward achievement similar to the USGBC LEED rating system. Utilizing accepted industry criteria to establish the minimum requirements for the designs. The baseline energy model along with the minimum performance requirements and benchmarks for additional points will be established by ASHRAE 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings. Achieving efficiencies over the base line such as greater efficiencies of ten percent, twenty percent and thirty percent achieve additional point rewards toward meeting the minimum point total established by the owner. Similar rewards are available for construction time increases resulting from efficiency in the use of materials achieved by prefabrication and preassembly. Any reductions in labor achieved through prefabrication, preassembly and repeatability of design details will receive points. To address construction worker Sa, the PtD concept will be included as part of the designers’ responsibility to the owner. The campus owner will specify the required total points the design team must achieve before permitting the building design to proceed into the next phase.

There are two main parts to the BDSSMAS, 1) an excel spreadsheet and 2) individual word documents. The spreadsheet provides a method for accounting for the points achieved. The points are awarded based on meeting the goals established by the owner such as; energy efficiency greater than the based line in ASHRAE 90.1, prefabrication, Panelization, standardized structural grid, etc. These point totals are dcoumented in the meeting agendas in the system and the spreadsheet tracks the total points for the phase.

The word documents are the meeting minutes and decisions recorded for each segment of the BDSSMAS. During the design process, the designer must document meeting discussions based on the meeting agenda in the system reviewing the design decisions against Co, B, Su, Sa, and M. Also, the constructor must include in their Co review, spaces for comments by others (designer and owner) on the effect of the Co comment on B, Su, Sa and M. This will ensure thedesign decisions and the Co review comments are considered in light of the other concepts.

5 Research Objectives

The literature illustrates a gap in the available tools for the campus owner to manage the technologies used in the construction of their buildings in a systematic fashion. The body of literature has demonstrated the benefits of Co reviews, B reviews, Su design and construction practices, M, and Sa in design. Currently, designers apply these different aspects of building design separately and inconsistently. However, the literature also shows little research has been conducted on a single model to combine Co, B, Su, M, and Sa. Therefore, this research will examine the following questions;

- Will providing a unifying system to manage Co, B, Su, M, and maintenance worker Sa result in more efficient use of resources?
- Will the application of the BDSSMAS result in a more consistent application of Co?
- Will the application of the BDSSMAS result in a more consistent application of B?
- Will the application of the BDSSMAS result in a more consistent application of Su?
- Will the application of the BDSSMAS result in a more consistent application of M?
- Will the application of the BDSSMAS result in safer buildings to maintain?
- Will the application of the BDSSMAS result in lower construction costs?
- Will the application of the BDSSMAS result in shorter construction schedules?

The mechanism to answer these questions will be through SME focus group discussions and an online survey to gauge the SME's opinions on the viability of a system to reqire designers to address the synergistic relations between Co, B, Su, M, and Sa for the maintenance worker.

6 Methodology

This research will be conducted using a sequential mixed methods model. A qualitative focus group phase will be followed by a quantitative survey phase. Kidd and Parshall [25] state "the overall sequence of qualitative exploration and theory development with subsequent use of quantitative data in a more confirmatory mode is fairly conventional." The BDSSMAS will utilize the best practices in Co, B, Su, M, maintenance worker Sa and conducted as a mixed methods research design. Creswell [26] explains the exploratory mixed methods design as a method in which the "first phase begins by exploring the qualitative data and analysis and then uses the findings in a second quantitative phase." Each of the phases will utilize different sampling techniques. The qualitative phase will utilize purposive sampling and the quantitative sampling will utilize convenience sampling.

The qualitative phase will be a series of scoping focus groups. As defined by Kaplowitz, Lupi and Hoehn [27] a scoping focus group is a questionnaire based design to "study the range of participant's responses of concepts being assessed."

Homogeneous focus groups will be assembled representing architects, constructors, AHJ, and campus owner representatives (project managers and facility maintenance personnel). Limited demographic data on the composition of the focus group will be collected to gauge the breadth of experience represented.

This phase of the research will employ the "micro-interlocutor" technique recommended by Onwuegbuzie, Dickerson, Leech and Zoran [28]. The technique accounts for the differences between SME participants' choices to remain silent or acquiesce to a more dominant member. The data obtained from the focus group may indicate the consensus view of the group but may indicate little about the different views expressed within the discussion. Therefore, examining the level of consensus within the group may provide richer data by examining the proportions in agreement, in opposition or noncommittal to the consensus view. In addition, the descriptive statistics on the consensus reached will be included in the analysis.

The second phase of this research will be an online survey. Demographic information such as years of experience, familiarity with the concepts, gender, and education level will used to demonstrate breadth of knowledge across the SME groups. The collected data from the survey will be analyzed using Factorial ANCOVA statistical test. The SME groups will be the independent variables. The institutions and staes will be the covariates. The completed research will include descriptive statistics for each SME group.

The research is expected to provide confirmation that a more effective method of incorporating Co, B, Su, M, and Sa into the building design process will result in better efficiency in the use of materials, reduce construction costs, reduce construction schedules, and increase Sa through the implementation of the BDSSMAS.

References

1. National Institute for Occupational Safety and Health. (2016, 07 29). *Prevention through Design*. Retrieved 08 13, 2018, from Prevention through Design: https://www.cdc.gov/niosh/topics/ptd/default.html
2. Gambatese, J. A., Hinze, J. W., & Haas, C. T. (1997). Tool to Design for Construction Worker Safety. *Journal of Architectural Engineering*, 32-41.
3. World Commission on Environment and Development. (1987, 3 20). *Our Common Future.* Retrieved 10 15, 2018, from UN Documents: http://www.un-documents.net/our-common-future.pdf
4. Behm, M., & Hock, P. C. (2012). Safe Design of Skyrise Greenery. *Smart and Sustainable Built Environment, 1*(2), 186-205.
5. Behm, M., Lentz, T., Heidel, D., & Gambatese, J. (2011). Prevention Through Design and Green Buildings: A US Perspective. *Blueprints, 10*, 28-34.

6. Arditi, D., Elhassan, A., & Toklu, C. (2002). Constructability Analysis in the Designb Firm. *Journal of Construction and Engineering Management, 128*(2), 117-126.
7. Davis, V. S., & O'Connor, J. T. (1988). Constructability improvement during field operations. *Journal of Construction Engineering and Management, 114*(4), 117-128.
8. Radtke, M. W., Gugel, J. G., & Russell, J. S. (1994). Comparative analysis of three constructability approaches. *Journal of Construction Engineering and Management, 120*(1), 180-195.
9. Lam, P. T., Wong, F. W., & Chan, A. P. (2006). Contributions of designers to improving buildability ands constructability. *Design Studies, 27*(1), 457-479.
10. Fischer, M., & Tatum, C. B. (1997). Characteristics of design-relevant constructability knowledge. *Journal of Construction Engineering and Management, 123*(3), 253-260.
11. Young, I. J. (1998). Constructability in the design firm. *Cost Engineering, 40*(2), 33.
12. Paulson, Jr., B. C. (1976). Designing to Reduce Construction costs. *Journal of the Construction Division, 102*(C04), 587-592.
13. Building Code Authority. (2017, April). 2017 Edition. *Code of Practice on Buildability*. Building Code Authority.
14. Crowther, P. (2002). Design for Buildability and the Deconstruction Consequences. In A. R. Chini (Ed.). Karlsruhe, Germany.
15. Seeley, I. H. (1987). Nature and Importance of Building Maintenance. In *Building Maintenance. Building and Surveying Series.* London: Palgrave,.
16. Construction Specifications Institute. (2011). *The CSI Project Delivery Practice Guide.* Hoboken, New Jersey: John Wiley & Sons, Inc.
17. Asmone, A. S., & Chew, M. L. (2018). Merging Building Maintainability and Sustainability assessment: A Multicriteria Decision Making Approach. *Earth and Environmentaal Science. 117*, p. 12029. IOP Publishing Ltd.
18. Chew, M. Y. (2016). *Maintainability of facilities: Green FM for building professionals* (Vol. Second Edition). Singapore: World Scientific.
19. Chew, M. Y., Conejos, S., & Asmone, A. S. (2017). Developing a Research Framework for the Green Maintainability of Buildings. *Facilities, 35*(1/2), 39-63.
20. Pulaski, M. H., & Horman, M. J. (2005). Organizing Constructability Knowledge for Design. *Journal of Construction Engineering and Management, 131*(8), 911-919.
21. Hollmann, J. K. (2004). Strategic Asset Management. In S. J. Amos (Ed.), *Skills & Knowledge of Cost Engineering* (5th ed., pp. 26.1-26.10). Morganton, WV: AACE International.
22. Ying, L. J., & Pheng, L. S. (2007). Enhancing buildability in China's construction industry using Singapore's buildable design appraisal system. *Journal of Technology Management in China, 2*(3), 264-278.
23. Taylor, E., Hignett, S., & Joseph, A. (2014). The environment of safe care: Considering building design as one facet of safety. *Proceedings of the International Symposium of Human Factors and Ergonomics in Healthcare*, *3*, pp. 123-127. Chicago.
24. Szymberski, R. (1997). Construction project safety planning. *TAPPI Journal, 80*(11), 69-74.
25. Kidd, P. S., & Parshall, M. B. (2000). Getting the Focus and the Group: Enhancing Analytical Rigor in Focus Group Research. *Qualitative Health Research, 10*(3), 293-308.
26. Creswell, J. W. (2014). *Research Design: Qualitative, Quantitative, and Moxed Methods Approaches* (4th ed.). Thousand Oaks, California: SAGE Publications, Inc.
27. Kaplowitz, M. D., Lupi, F., & Hoehn, J. P. (2004). Multiple Methods for Developing and Evaluating a Stated-Choice Questionnaire to Value Wetlands. In S. Presser, J. M. Rothgeb,

M. P. Couper, J. T. Lessler, E. Martin, J. Martin, & E. Singer (Eds.), *Methods for Testing and Evaluating Survey Questionnaires* (pp. 503-524). Hoboken, NJ: John Wiley.

28. Onwuegbuzie, A. J., Dickinson, W. B., Leech, N. L., & Zoran, A. G. (2009). A Qualitative Framework for Collecting and Analyzing Data in Focus Group Research. *International Journal of Qualitative Methods, 8*(3), 1-21.