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TRANSFORMATION-FLOW-VALUE VIEWS OF A COLORADO SCHOOL DISTRICT'S PROTOTYPING STRATEGIES

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ABSTRACT

Key issues and strategies used by a school district in Colorado for the procurement and implementation of prototype designs for its buildings were examined in the exploratory study presented here. School construction prototyping involves the design and building of a project with the deliberate purpose of repeating it multiple times while allowing its constant improvement. The practice has been reported as having failed when attempted in several states, but it is currently a successful, standard practice of the researched school district. Issues were separated into those significant to the school district and those significant to the prototype designer. To clarify their taxonomy, issues were grouped into categories consequent to Koskela's process paradigm of Transformation, Flow and Value.

KEYWORDS

Standardization, customization, school prototypes, TFV paradigm.

BACKGROUND

School districts need to expand their capacity with limited or even shrinking funding. The need for more schools in the United States is underscored by documents such as the American Society of Civil Engineers' Infrastructure Report Card (2013), which indicates that almost one in ten public schools in the United States reports enrollment exceeding the building's permanent capacity by more than 25%. If this trend continues, significant new school construction will be required to meet space demands in an environment where construction needs are often limited by funding challenges. For example, in Colorado no state capital funding is allocated to school construction, placing the expansion cost burden on each school district (21st Century School Fund, 2014, Colorado Department of Education, 2014).

For tighter financial control, public school districts sometimes perform design and project management functions to satisfy space and building program needs, although such functions are outside their core competency of educating students. A challenge of such unique designs is that there is no capturing and integration of usable knowledge resulting from each one. This is especially true when each successive design proceeds from a different architect, who probably will be reluctant to share the design with the

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next project's architect. A building can be excellently designed and built, and yet its design could be ignored in the next project.

PROTOTYPING

Prototyping can offer an effective solution to learn from previous projects and reuse best design practices. The term prototype as used here refers to a project or major component of a project designed and built with the intent of repeating it multiple times (California State Allocation Board, 2000). Each instance of a prototype is considered a project. Since the design and construction of schools tend to have similar objectives and requirements, prototypes are attractive to school districts. Prototyping offers school districts the promise of improving efficiency, capitalizing on lessons learned and reducing costs in design and construction while avoiding duplication of mistakes **(**DeKalb County Board of Education, n.d.).

It has been claimed that prototyping has been used since at least the 1860s in Ireland (OECD Centre for Effective Learning Environments CELE, 2011). Non-scientific reports have been available from the 1960s and even earlier (Council of Educational Facility Planners International (CEFPI), (2009). A literature review for this study showed a scarcity of scholastic literature about the benefits and drawbacks of this approach, perhaps influenced by the fact that the term *prototype* as used here differs from its more common interpretation of a preliminary stage towards a final product. For example, Howell and Ballard discuss the nature of a construction project within the context of Lean Construction as being “analogous to the preparation of a prototype” (Howell, G. and Ballard, G., 1997), implying the most common use of the term *prototype*. The term is common in the technology industry, although also used as a near-synonym for a preliminary stage in software or hardware development. Another example can be found in Sacks, Ronen, Belaciano, Gurevich and Pikas (2013), which describes an early tool of a new information system developed by the authors as “an early prototype of a novel workflow management information system for construction”.

CURRENT CONDITIONS

USE OF PROTOTYPING

Several countries report a successful use of prototyping and using it as a standard practice for school construction. The OECD Centre for Effective Learning Environments (CELE), (2011) discusses the experiences of several countries with prototyping, such as the province of Alberta, Canada, which claims to have saved CAD 97 million between 2007 and 2011 along with two years of saved construction time. The report also mentions that between 1959 and 1970 Mexico built and furnished 54,000 classrooms and has used the experience for its current standard designs. Comparable levels of success for school prototypes are included in the OECD report for Australia, Brazil, Portugal and other countries.

Reports about the use of prototyping for school building construction have been commissioned and published in the U.S. mainly by state legislatures, school districts and professional associations. While some districts show enthusiasm for this approach (e.g., Horry County Public Schools, n.d.), many other reports have found significant drawbacks on the use of prototypes. One of the most comprehensive compilations of such shortcomings is the State of Arkansas Public Relations Committee's report on prototypical building designs (2004). It asserts that prototyping would need "a large staff" of architects and engineers to update the plans, it would eliminate competition, require a large number of designs, adjusted to code that "change yearly", consider diverse seismic conditions, an architect would be still needed for each project, and the "liability question all but eliminates any money saving of architect's fees". Its accuracy is negatively impacted by stating that only four states of 41 surveyed by a previous study reported ever using prototypes. Colorado and California were among the states reported as not using this design approach, despite evidence of its use in both states, as discussed in the next paragraphs. Moreover, the American Institute of Architects, reports that 25 states have used prototyping (American Institute of Architects, 2005).

Other studies contain negative considerations about prototyping (e.g., CEFPI, 2009, Alaska Department of Education & Early Development, 2015, DeKalb County Board of Education, n.d.), although less radically than the Arkansas report. Criticism about prototyping includes the lack of community involvement in the design process of a given school (Department of Education, Commonwealth of Virginia, 2002), the costs associated with customizing a design to a particular site conditions, the design differences for elementary vs. middle and high school programs, rural vs. urban districts and small vs. large districts (Alaska, 2015). It has been reported that "Prototype school designs save time, money; critics say schools lack identity." (Gray, 2014).

A promising approach has been called "kit of parts" (CEFPI, 2009) consisting of the partial application of prototyping by zones. A clearinghouse of best practices maintained by the School Planning Section of North Carolina Department of Public Instruction (n.d.) provides a useful source for designers.

The California State Allocation Board (CSAB) Public School Cost Reduction Guidelines (2000) are an important and deliberate effort to comprehensively address school prototyping issues. The guidelines were developed by construction expert workshops as a way to reduce construction process costs and to determine best practices and critical success factors for new public school building construction. This study utilizes with only minor modifications the division of prototyping issues contained in these guidelines.

DOUGLAS COUNTY SCHOOL DISTRICT

This study centers on the prototyping practices of the State of Colorado's Douglas County School District (DCSD), which serves suburban areas and towns immediately south of Denver. It has experienced large enrollment growth and capital expansion in recent years, resulting in the construction of a substantial number of new school buildings. Currently there are approximately 67,000 students currently enrolled in the district, ranking it as the third largest in Colorado and 59th largest in the United States. The District operates 48 elementary schools, nine middle schools, and nine high schools with a total budget of nearly $700M (2013-2014 school year) and 7,000 employees. In addition, enrollment is expected to double over the next twenty years (Douglas County School District, 2016). DCSD has used prototypes for years for new school building construction of more than 50 schools. The use of prototyping is considered to have minimized construction costs, design fees, and project schedule duration (Colorado Governor's Energy Office, 2013).

DCSD has achieved considerable success with the use of prototypes for its new school building projects. This study's interviewee reports that prototyping has saved DCSD about 25% in design fees and 17%-18% in construction bids. Furthermore, the use of prototypes has saved up to six months in total development and construction time when used in repeated designs. This study did not attempt to compare these notable results with performance at other school districts.

Some key DCSD management personnel involved in the district's use of prototypes are close to retirement. The experience of these individuals are at risk of being lost when they retire. An important motivator of the present study was the preservation of their knowledge to the greatest possible extent.

OBJECTIVES

This paper presents the results of a pilot study which investigated key issues faced by DCSD concerning the design, procurement and management of its school building prototypes. A primary objective of the study was to serve as a reference for future administrators of this school district and a point of comparison for administrators elsewhere. A secondary objective of this study was to preserve the knowledge accumulated by some key DCSD management personnel involved in the district's use of prototypes who are close to retirement. The study was intended to serve as a compendium of key DCSD's practices, but did not attempt to compare them to other school districts' policies or whether school building prototyping has merits to be generally recommended.

THEORETICAL FRAMEWORK AND METHODS

The method for this case study involved the collection and analysis of public information and in-depth interviewing of the DCSD's administrator for school construction. It followed the standard in-depth interview methodology of thematizing, designing, interviewing, transcribing, analyzing, verifying and reporting. In-depth interview research cannot be subject to the generalization standards of quantitative research. Its objectives are built around program refinement, issue identification, and strategic planning (Guion, Diehl, and McDonald, 2011). These limitations restrict the use of in-depth interviewing to exploratory studies such as the present one.

The issues addressed here follow the breakdown of topics in the CSAB's guidelines (CSAB, 2000), and were grouped into categories consequent to the process criteria of the Transformation-Flow-Value (TFV) paradigm developed by Koskela (2000). Although primarily focused on the understanding of production processes, the TFV paradigm has a broad philosophical scope, allowing its use for the taxonomy of issues addressed by this study.

Koskela has used the term "world views" to refer to the division into Transformation, Flow and Value, since they reveal comprehensive assumptions about reality and management of reality. The Transformation view focuses on the realization of value adding activities. It is the *What* of the investigated reality; the Flow view is focused on reducing the share of non-value adding activities. It is the *How* part of reality; in the Value view, the focus is the improvement of customer value. It is the *Why* view. The left side of Figure 1 is a compact summary of the TFV paradigm shown on Table 4 of Koskela (2000), providing more detail about these definitions, used as guidelines for the grouping of the CSAB's issues discussed here.

An analysis of collected information, particularly the interview transcript from the DCSD's main construction administrator, led to the grouping of District and Designer issues under the Transformation, Flow and Value views. This grouping was ultimately subjective, although a thematic analysis of the interview and published data provided consistency to the assignments. The opinion of the main construction administrator was also instrumental to the details in the list. The right side of Figure 1 contains the issues addressed here and their grouping under Transformation, Flow and Value. The use of the TFV paradigm as the basis for the static taxonomy of this study provided insight into the underlying dynamics of DCSD's management processes concerning prototyping.

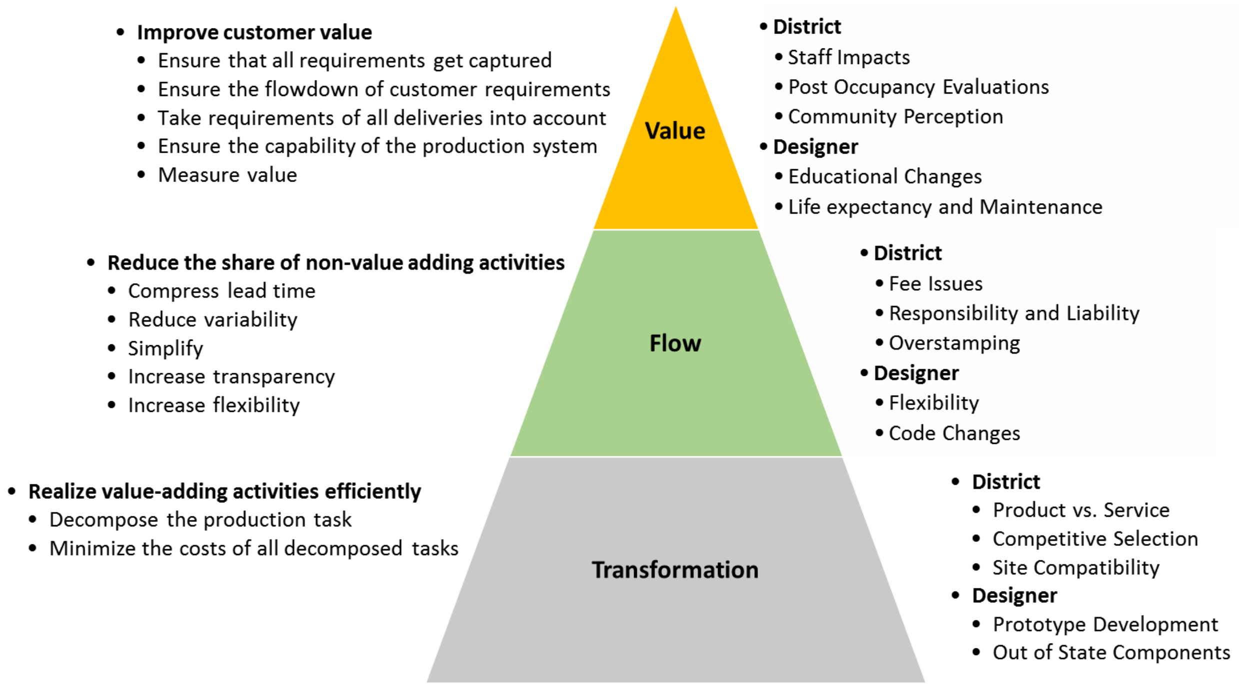

Figure 1: TVF Principles and Addressed Issues

FINDINGS

The following findings summarize the issues addressed by this study. As previously discussed, these findings resulted from public records and in-depth interview and consultation with the district's main construction administrator.

PRACTICES UNDER THE TRANSFORMATION VIEW

Issues under the Transformation view concern tasks for the input and output of the prototyping process, paralleling Koskela's partial description of Transformation as acquiring the inputs to these tasks with minimal costs and carrying on the tasks as efficiently as possible." (Koskela. 2000).

District Considerations

- **Product vs. Service.** DCSD begins prototype design projects by negotiating terms for subsequent projects that make use of the same design. Clarification of this diminishing role of the designer early in the process works to mitigate concerns of declining professional services with prototype use. Setting the expectation for a limited prototype life span addresses this concern.
- **Competitive Selection.** DCSD manages competitive selection by hosting design competitions complete with stipends to encourage participation and fair and open competition within the architecture community. The selected designers can, eventually improve their own existing prototypes as their repeated use serves to detect flaws in design or construction.
- **Site Compatibility**. A major lesson learned from the regular use of prototypes has been the development of features relatively easy to adopt by various site situations, especially in their ability to adjust foundations to differing soil conditions.

Designer Considerations

- **Prototype Development**. DCSD requests designs based on changes in funding, community preference, and educational program needs. Although the district has found that the initial development of prototypes can be more time intensive than a unique design, a prototype development is most successful when all factors such as program-driven space needs, community preferences and input, district standards, and funding implications are considered.
- **Out of State Components.** Impacts of factory-built components have been limited in DCSD projects by the district's design and materials selection policies. Products from out of state or non-compliant with code requirements without modification are avoided as much as possible.

PRACTICES UNDER THE FLOW VIEW

The issues grouped here under the Flow view address the "minimizing [of] the share of non-transformation stages of the production flow, especially by reducing variability." (Koskela, 2000). The issues below, accordingly, concern the stabilization of the prototyping process, especially from the district's viewpoint.

District Considerations

- **Fee Issues.** DCSD negotiates an initial fee for each prototype design with its designer and contracts each prototype separately. Fees for prototypes can be lower per project when compared to unique designs and that fee issues can be resolved through negotiated agreements for each project independent of other concerns. This approach leads to a lower average designer fee per project.
- **Responsibility and Liability**. The ownership of prototype designs may come with liability of design flaws and other complex legal concerns. DCSD manages these issues by stating intent to reuse and improve prototypes during the design phase, taking ownership of the designs, keeping the original consultants involved, and selecting one architect of record. A particular challenge faced by other district is the design's **overstamping.** States such as California require any design to be stamped by a single architect regardless of the number of

contributing designers. Colorado does not require single-stamping, thus avoiding this substantial ownership dilemma.

Designer Considerations

- **Flexibility**. DCSD requires the use of prototype designs with the flexibility to adapt to new educational requirements. Designers (and most educators) cannot project in detail new educational approaches or mandates, and therefore, this requirement results in designs with scalable features varying from relatively small changes, such as room use and layout, to large ones such as wing expansion and knockout walls. Flexibility is enhanced by DCSD's strategy of "kits of parts", close to the recommendations of the Council of Educational Facility Planners International (2009) previously discussed. The initial design process flow is larger than if a single design is prescribed, but the design flow is stabilized by the larger number of valid alternatives for subsequent repetitions.
- **Code Changes.** Changes in code requirements that are adopted between the creation of a prototype design and its use may require updates and changes in design and construction that may reduce the prototype's value. DCSD mitigates the impact of future code changes by designing the initial prototype to exceed safety and efficiency standards of current code and actively participating in design updates. As in the case of flexibility issues, the aim of these initial precautions is to avoid instability in the future.

PRACTICES UNDER THE VALUE VIEW

The Value view "views production as a means for the fulfillment of customer needs. Production management equates to translating these needs accurately into a design solution, and then producing products that conform to the specified design." (Koskela, 2000). While the internal customers of a school district are its students and indirectly the students' families, its ultimate, external customers are the taxpayers funding the district's operations (in the case of the U.S., parents of the district's student population are also important external customers, directly paying for about a third of the school's expenses through their school mill levy). Issues under this view concern the value of a prototype to their customers. In the case of the DCSD, the key practices presented below emphasize the feedback to its staff and the community.

District Considerations

- **Staff Impacts.** As a strategy to demonstrate the value of prototyping to its staff and to reduce the impact of required expertise outside the district's staff experience, DCSD has chosen to use the Clark County School District of Nevada (Clark County School District, 2012) as a resource and model. The Nevada District had previously used prototype schools to respond to rapid population growth. Learning from a peer district minimizes initial negative impacts of prototyping in terms of learning curve and lessons learned from the district's viewpoint.
- **Post Occupancy Evaluations (POEs)**. The objective of POEs is to improve future designs through feedback from occupants, owners, and other stakeholders. DCSD conducts POEs to analyze successes and areas for improvements. For example, bid and construction process for one project may

need to begin before the POE from the most recently completed prototype is available, requiring lessons learned from a previous iteration to be used as the primary source of feedback.

- **Community Perception.** DCSD is aware of the importance of maintaining the community aware of its plans, and explains in advance the nature of prototypes. This strategy provides value in both directions: the community can provide input to the process, and DCSD can explain its plans.

Designer Considerations

- **Educational Changes.** The flexible spaces and adaptable features to address future educational changes are critical success factors for district consideration with prototypes. Designers must show vision and creativity for this changing factor, which they cannot know in any detail.
- **Life expectancy and Maintenance**. DCSD has found that prototype design enhances value engineering through repetition and allows experience to guide design and purchasing decisions to increase both service life and efficiency of the buildings.

DISCUSSION

DCSD emphasizes clarity on the roles of the many stakeholders in the construction of a school building prototype, and particularly on the definition of the district's relation with the prototype designer. From the designer's viewpoint, the challenges and strategies are different but interlaced with the district's.

- **Transformation view.** The *What* of the prototyping process is centered on the definition and selection of the designer and its services for DCSD, and in the tangible result of the design for the designer. This district is large and in need for solutions to its rapid growth, and its constituency is relatively uniform in key socioeconomic aspects (Douglas County School District, 2016). Size, growth and student body uniformity have been singled out by at least one report (Alaska, 2015) as ideal for the implementation of school prototypes.
- **Flow view.** The *How* is centered on the stabilization of the design and procurement process flows. For the most part, this is as a set of issues and strategies about the short and long-term cost and liability of the design effort. DCSD's approach toward these issues is the selection of a single designer for each prototype. From the designer's viewpoint, the challenges are more standard in the sense of involving creativity and vision for designs that can be tailored to a particular case and be updated to future building code requirements.
- **Value view.** The *Why*, from DCSD's perspective, involves the value to its customers deriving from the use of prototypes. The deliberate use of peer districts' experiences has simplified the learning and management of prototypes. DCSD follows a proactive policy of information and feedback with the district's stakeholders through POEs and community education about upcoming projects, which has clarified the value of prototyping to its customers.

CONCLUSIONS

This study provides a summary of successful practices for the implementation of prototyping by the DCSD as evaluated by its main construction administrator and supported by published information. The issues have been broken down using the guidelines of the California State Allocation Board (2000), and grouped under Koskela's (2000) TFV process paradigm. The study provides descriptive as opposed to prescriptive information, as its main purpose was to offer a rational taxonomy of the successful practices followed by DCSD.

The successful practices followed by DCSD contrasts with the reported failures of some other school districts attempting to implement a policy of school construction prototyping. The district has many of the positive factors mentioned by other reports addressing the use of prototyping, such as being a large, growing district with personnel willing to learn the virtues and limitations of this designing approach.

Given the reduced scale of this study, this paper does not attempt to compare DCSD's performance with that of other districts. While this study's results show the promise of obtaining positive results when a consistent approach to procure and manage school prototype designs is used, other districts may have different circumstances warranting different solutions. Further research should consider the value and limits of school prototypes as a response to the current circumstances of K-12 education.

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