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Leveraging previously reported research to create a decision support tool for institutional facility maintenance

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Abstract

Purpose – The discretionary expense budget required to maintain public infrastructure has declined in recent years, even as public expectations and accountability for performance have increased. The purpose of this paper is to leverage previously reported research to create a decision support tool (DST) for prioritizing institutional facility maintenance.

Design/methodology/approach – A structured literature review was developed to identify critical aspects of facility maintenance shown to have a positive relationship with academic performance in K-12 schools within the USA. Analytical hierarchy process (AHP) serves as a framework for a multi-criteria DST based on the findings of the literature review. Finally, a targeted focus group of industry professionals was used to validate the usability of the resulting DST.

Findings – The framework for the DST developed for this study effectively represents the scale and scope of an institutional facility. Results of the study suggest that when evaluating multi-criteria work orders, the proposed visual AHP methodology can be used to generate usable DSTs to assist with the prioritization of work.

Practical implications – This study provides a methodology for building a multi-criterion DST leveraging precedent research, using a visual AHP to assist facility management (FM) decision-makers in the prioritization of routine work orders.

Originality/value – The developed process indicates a practical approach to incorporating disparate research findings into a concise and useable manner to guide FM decision-makers, who have traditionally not been able to explicitly leverage this information to make evidence-based spending decisions.

Keywords Analytical hierarchy process, Facility management, K-12 education, Public institution

Paper type Research paper

Introduction

Within the USA, federal and local governments are increasingly faced with constrained resources while managing a vast amount of building infrastructure, ranging from schools to stadiums to hospitals. The primary purpose of these facilities is to serve a public function deemed necessary and commonly understood to be of public benefit. Institutional facilities must, therefore, be managed and maintained expertly to serve their intended purpose while in operation.

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Frequently, this process of maintenance requires facility managers to prioritize work in a manner that best supports the intended purpose of the facility. In other words, for these types of institutions, facility managers are often inundated with requests to address reported building problems (i.e. replace a burned-out light or adjust the temperature for a given space). Often there are more of these types of work order requests than there are available personnel or resources to address them. The subsequent backlog creates a need to prioritize work orders, resulting in the completion of those work orders deemed most important and of highest priority. Others that are determined to be less critical may be delayed or dispositioned, based on the facility manager's judgment.

This process of informed prioritization and subsequent completion of work orders can have a significant impact on the overall performance of a building and the performance of those people working in a facility. Many research publications, as well as anecdotal evidence, indicate that poor facility conditions can hinder operational performance. For example, there is a variety of institutional research, specific to kindergarten through 12th grade (K-12) education, indicating that attributes of the built environment can have a direct impact on student performance (Cash, 1993). This impact can be beneficial or detrimental, depending on the specific condition. While most prior studies do not explicitly state that effective facility management (FM) can directly lead to better student performance, it is clear that effective FM can impact the condition of a built space, which prior works have indicated can impact student performance. Furthermore, prior research that explores trends in the performance of various public institutions indicates that there are opportunities for significant improvements in the way buildings are managed, including K-12 specifically (Beauregard and Ayer, 2018) and other public institutions in general (Amaratunga and Baldry, 2003; American Society of Civil Engineers, 2001; Herrmann, 2013). This highlights the opportunity for decision-makers to directly leverage the findings of prior research to prioritize work based on what has been reported to be beneficial for the overall performance of a facility.

While the potential need for a better decision-making process in public institutions may seem apparent from a cursory review of the literature, the process for guiding decision-making is less transparent. Therefore, this work proposes a methodological approach to create a decision support tool (DST) that leverages existing literature that specifies attributes of the built environment that may benefit the overall performance of the institution. This approach leverages principles suggested by analytical hierarchy process (AHP) literature and also includes methods for identifying and organizing existing literature related to building performance. The developed tool is intended to be comprehensive, yet easy-to-use, enabling building managers to implement the tool on a daily basis.

The authors chose to use K-12 education as the field for testing this DST development approach. There is a wealth of published literature related to attributes of the built environment that impact student performance, and there is also an opportunity for improvement for K-12 infrastructure. While K-12 was the focus of the study, the authors aimed to create a methodology that could be used to generate evidence-based DSTs for other types of building environments that require work order prioritization. The developed DST was validated using a targeted focus group of industry professionals and includes four primary FM categories. The DST structure and overall process used for development of the DST are envisioned to be usable for a variety of building applications. The contribution of this work is in providing a reusable methodology that may be implemented to create subsequent DSTs for enabling evidence-based decision-making among building managers in various built environments.

Background

The U.S. Federal Government is the nation's largest institutional property owner and manages more than 3.3 billion square feet of real estate, which costs more than $30bn

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annually (US General Services Administration, 2012). The portfolio of federal properties includes 43 million gross square feet (GSF) of correctional facilities, 266 million GSF of educational space and almost 130 million GSF of hospital facilities (US General Service Administration, 2018). The U.S. Postal Service alone manages approximately 30,000 sites across the nation (US General Service Administration, 2018). The list of institutional facilities includes public parks, universities, school districts, transit sites, police and fire stations, courthouses, correctional facilities and similar governmental properties requiring regular preventive, predictive and corrective maintenance.

The ability of a facility operations organization to successfully integrate the management of building infrastructure maintenance with the strategic near- and long-term objectives of an institution contributes to an environment that supports the primary objectives of that institution (Barrett and Baldry, 2009). When appropriately managed, the FM organization can positively impact an institution’s end requirements (Becker, 1999). Similarly, the metric of institutional facility efficiency may be realized as that institution’s success in creating public value (Amaratunga and Baldry, 2003; Tucker and Pitt, 2009).

While many different factors can impact overall FM performance, one of the critical tasks that must be accomplished among FM teams relates to the prioritization and completion of routine work orders that support the quality of the built environment and enable overall organizational effectiveness. Facility managers and directors are typically responsible for assigning priority to routine maintenance requests (work orders). While some evidence suggests opportunities for this prioritization process to be improved (Beauregard and Ayer, 2018), these managers are tasked with a complicated job that frequently requires them to balance competing interests. They must prioritize work orders to utilize institutional resources efficiently, support a financial return on investment, support organizational performance, maximize assets, assess environmental impact and most recently anticipate social awareness (Alexander, 2013). Furthermore, they may face a host of issues internal to facility maintenance including continuous operations, optimized performance, human resources and the active integration of FM with the parent business or institution (Tay and Ooi, 2001). Therefore, the authors of this paper do not aim to suggest that the current facility managers are failing at their jobs. Instead, the authors suggest that the current environmental factors that surround work order prioritization make it nearly impossible for any individual to consistently make spending decisions that will always provide the most significant positive impact on a facility. For this reason, the authors aim to create a structured DST aimed at supporting consistent evidence-based spending decisions to empower decision-makers.

Academic districts

This research studies the prioritization of work at institutional facilities, using the public K-12 education system as a paradigm. Prior research frequently suggests a relationship between the condition of educational buildings and academic performance (Earthman, 2002; Earthman and Lemasters, 1998). More specifically, research has shown relationships between the built environment and various factors, including teacher retention (Buckley *et al.*, 2004; Earthman and Lemasters, 2009); school culture (Bejou, 2013); and academic climate (Billings and Terkla, 2014; Tanner, 2008). Similarly, a 2002 study by Amaratunga and Baldry identified a positive correlation between facility condition and organizational performance (Amaratunga and Baldry, 2003). These prior works collectively highlight the potential for FM organizations to use prior evidence when guiding work order prioritization.

Despite these opportunities for K-12 spending decisions to impact student performance, data from the National Center for Educational Statistics shows that funding for routine

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facility maintenance in support of education infrastructure is in a state of decline (Snyder *et al.*, 2016). Presently, many K-12 organizations are resorting to a deferred maintenance approach for prioritizing spending (Alexander and Lewis, 2014). For example, facility maintenance spending for K-12 education buildings in the state of Arizona was $1,170 per student for the 2003 academic year, which equates to approximately $1,430, when adjusting for inflation. In 2014, the annual spend per student totaled $922, a decline of approximately 21 per cent. Over this same period, student enrollment in Arizona's K-12 educational system increased by more than 26 per cent (NCES, 2014). Moreover, the National Center for Educational Statistics estimates the states K-12 enrollment will continue to grow by another 9 per cent by 2027. While the exact enrollment and spending trends vary by state (Hunting, 2013), the need for the USA's K-12 academic institutions to perform better with fewer resources is consistent among many states. When considered in conjunction with the wealth of prior literature indicating specific attributes of the built environment that may uniquely support academic performance, this highlights a significant opportunity for a structured decision support tool to offer value to FM decision-making.

Analytical hierarchy process as a decision support tool for facility management

The authors of this paper leverage principles of AHP to guide FM decision-makers to leverage findings reported by prior research. AHP provides a technique for handling uncertain multi-criteria information, using pair-wise comparisons while leveraging the experience of subject matter experts (SMEs) to derive priorities objectively (Saaty, 1999, 2008). The selection of AHP as a decision method provides insight where existing decision protocol such as life cycle asset management, return on investment and net present value do not address both the economic and analytical factors influencing the decision process (Chan *et al.*, 2000). AHP has been practically applied as a decision support archetype for health-care facilities (Lavy and Shohet, 2007), building maintainability (Das *et al.*, 2010), facility benchmarking (Gilleard and Wong Yat-lung, 2004), building renovation (Nielsen *et al.*, 2016) and residential asset management (Shen *et al.*, 1998; Vilutienė and Zavadskas, 2003), along with many other relevant aspects of construction and building management. This research contributes to the existing body of work applying AHP as a decision framework. The methodology for organizing previously unstructured research into an easy-to-use DST for routine FM indirect expense, specific to large-scale institutional facilities, constructively expands upon the existing research.

Methodology

The process for developing a DST that leverages prior research for prioritizing FM spending was created through four sequential steps (Figure 1). A comprehensive literature review was initially developed to identify, and then aggregate, institutional performance enablers specific to facility infrastructure and K-12 education. Researchers then selected AHP as an archetype decision support methodology based on AHPs ability to facilitate complex, multi-variate, problems. Moreover, AHP provides SMEs a vehicle to influence their decisions.

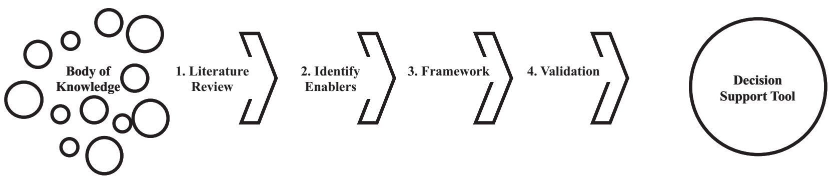

Figure 1.
Four-step research method

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A framework was then constructed, based on K-12 education, to enable decision-makers to determine the extent to which a given work order would align with building attributes suggested to enable student success. Lastly, researchers convened a targeted focus group consisting of practicing facility directors, technicians and SMEs for validating the feasibility and practical application of the developed DST. The resulting process provides a reusable method for developing a DST that leverages existing research aligned with institutional objectives for the prioritization of routine work orders. This section describes the process for development of the DST.

Step 1: literature review

A literature review of academic publications documenting the relationship between facility condition and institutional performance (academic outcomes) provides the underpinning for this research. Researchers considered three publishers' databases (Elsevier, Emerald Insight and Taylor & Francis) compiling and aggregating a comprehensive body of knowledge for this study. These bibliographic databases were selected because they all have high-quality peer-reviewed publications that specifically relate to the practice of FM, facilities and education.

Prior research has identified a positive correlation between facility condition and organizational performance (Amaratunga and Baldry, 2002). Comparable studies have established a similar relationship between the condition of educational facilities and the academic outcomes of students (Earthman, 2002). Initially, search terms relating to facility attributes and building systems that may relate to institutional performance were selected based on previously published work (Cash, 1993). The scope of FM, however, extends beyond building systems and architectural attributes. Therefore, the authors expanded the list of search terms to include facility infrastructure attributed to the development of an institution's climate and culture as that correlation became better understood (Maslowski, 2001; Wang *et al.*, 1997). Climate (ambience) and culture (ethos) can be influenced by work orders addressing items such as signage, seasonal landscaping, repaint and custodial, which can collectively influence the performance of an organization (Kumari and Dhull, 2017).

After identifying relevant papers that relate facility conditions to organizational objectives, an additional layer of filters was applied to further refine the search results. Academic journals were first filtered to limit publications to only those dated from 1990 to 2018. Given the changes in FM such as technology innovation, building systems, maintenance management systems and asset management analytics, the filter excluded those studies that may now be out of date. Furthermore, if any publications in this time frame cited technologies or other practices that are no longer used, they were omitted from the analysis. Results were further refined to include only scholarly academic journals. Professional practice or academic publications, such as those published by the Building Owners and Managers Association, the International Facility Management Association and the Association for Learning Environments, although informative, were excluded from the search findings as these publications are not generally peer-reviewed. Furthermore, researchers omitted papers published as a result of conference proceedings. Often conference papers represent incremental findings that support larger research efforts published in peer-reviewed journals. By excluding conference proceedings, it enabled the researchers to prevent redundant findings that would artificially indicate greater importance from the same work previously published in various outlets.

The final filter used for this study narrowed the scope of research to a selected public institution: K-12 education in the USA. International studies have been published detailing a relationship between facility condition and academic performance (Hopland and Nyhus, 2015;

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Leung and Fung, 2005). The nature of educational funding and academic infrastructure in other parts of the world does not necessarily apply to domestic K-12 education. Interstate similarities with respect to instructional delivery, educational infrastructure, funding mechanisms and the assessment of academic performance provide an ideal environment from which to assess the viability of the DST domestically. Furthermore, where prior studies have documented the results of capital improvements to facility infrastructure (Edwards, 1991; Lewis, 2000; Maxwell, 1999), this study documents a methodology for prioritizing routine work orders, which are indirect financial expenses.

Step 2: development approach

The literature review intent is to understand the role of institutional facilities' infrastructure through the lens of K-12 education. This specific focus enabled the authors to identify fundamental aspects of educational infrastructure that have been suggested to have a positive relationship with academic performance. To organize these aspects of infrastructure, AHP provides an ideal decision framework as it allows for multiple independent variables according to how each variable serves the needs of the organization (Saaty, 1990). Moreover, AHP uses pairwise comparisons, relying on the assessment of SMEs to establish priority (Saaty, 2008). The process of AHP enables the user to categorize multiple independent variables based on the variables' ability to influence, and positively impact the organization. The framework of AHP is transferable, thereby allowing for the development of institution-specific solutions.

In selecting AHP as a method of prioritizing research, the authors had to address the trade-off between a precise calculation of preference with the practical usability of the tool. A distinguishing benefit of AHP as a decision support archetype is the pairwise comparison, allowing the decision-maker the ability to assign value and thus prioritize multiple variables. The challenge of adopting AHP as a decision method, however, is the eigenvalue method of calculating priorities (Saaty and Hu, 1998), which for some users presents a challenge. Using this traditional method, the final decision is ultimately a mathematical calculation accounting for both a weighted distribution and conditioning factors. For a large-scale institution, a proper pairwise comparison may quickly become labor intensive as facility SMEs are asked to evaluate and quantify hundreds of variables. Moreover, the perceived complexity of the mathematical calculations may inhibit adoption. Consequently, practitioners may revert to their initial subjective assessment rather than adopt the numerical pair-wise valuation (Scholz, 1983). This concern, if realized, would negate the whole motivation of developing a structured DST.

In response to this challenge, the authors chose an AHP structure that uses a five-stage (very high, high, moderate, low and very low) linear multi-attribute selection method to mitigate potential challenges related to the complexity that might be present for decision-makers (Baloi and Price, 2003; Boucher and Gogus, 2002). The resulting DST establishes priority through a linear visual assessment enabling the efficient prioritization of work. The simplicity of visual assessment was selected to support the practical adoption of the proposed tool. Moreover, a linear visual selection method provides a consistent and repeatable platform for evaluating maintenance and improving the accuracy of the work order prioritization.

Step 3: constructing a decision framework

Researchers selected four primary categories to serve as the principal framework for the DST: influence, building status, building usage and institutional enabler(s). Each category was selected based on either the universal application of the category or prior academic

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research establishing a positive relationship between the category and the successful operations of a facility. Furthermore, this structure allows the DST to first address operational (macro-level) categories of performance before narrowing the focus to those factors enabling operational success.

Within each category resides a secondary layer of variables specific to the targeted institution. This secondary layer of variables provides FM and operational administration the opportunity to customize the DST to the specific needs of their organization while also providing a platform by which to prioritize work orders aligned with the strategic objectives of that organization. The secondary variables within each category, for this study, are aligned with K-12 education.

Central to the development of each category is defining the voice of the customer (Griffin and Hauser, 1993). The prioritization of work orders is a method for value creation and responds to the needs of the customer. The allocation of resources, aligned with facility attributes is, therefore, prioritized according to those work orders that are systemic to the success of the customer, synergistic with the objectives of the organization or at some lesser level discrete (Palmer, 2003). For K-12 education, defining who the customer may or may not be can be difficult and may be politically charged. This study defines the teacher–student engagement as the customer, given that academic performance is the primary measure of success for academic districts (Christenson *et al.*, 2012; Wang *et al.*, 1997). The term systemic, specific to K-12 facility maintenance, addresses those facility characteristics with the most significant impact on the delivery of education. The following paragraphs summarize the process of identifying each category and subsequently selecting the variables.

The first category, "influence," addresses "Who is most likely to benefit from completing the work order and what is their role in creating value?" Traditionally the owner is responsible for creating value and is, therefore, the primary stakeholder or customer in the maintenance and operations of a facility (Alshubbak *et al.*, 2015). Similarly, the selection of influence as the primary category of the decision support framework recognizes the department, team or individuals most capable of generating value for the organization. A report by the Mid-Atlantic lab for student success identified "classroom management" and "student/teacher social interaction" as two primary factors in the delivery of education (Wang *et al.*, 1997). Hence, concerning K-12 education, researchers identified the teacher as the primary customer having the most influence generating value for an academic district and is, therefore, the FMs primary customer (Griffin and Hauser, 1993). The priority given to other organizational roles and responsibility, such as district or school administration and support staff, declines as the intended work moves further away from the teacher-student engagement.

The second category, "building status," represents the relative importance of the building or space regarding function and usage (Shen, 1997; Spedding and Holmes, 1994). The category, therefore, prioritizes work orders that have the most significant effect on the overall institution. For example, building systems such as cooling towers or boilers may service an entire site, warranting a higher FM priority. By contrast, the risk associated with the failure of a lighting ballast may be limited to the given range of the failed light. Moreover, the surrounding light fixtures or natural day-lighting may supplement the failing ballast. Therefore, a work order associated with an overhead fluorescent light may, therefore, be a lower priority than a work order associated with primary building systems, such as cooling towers. Concerning K-12 education, work orders impacting an overall campus are assigned a higher priority than an alternate work order that may service a building, a classroom or a single administrative office (Figure 2).

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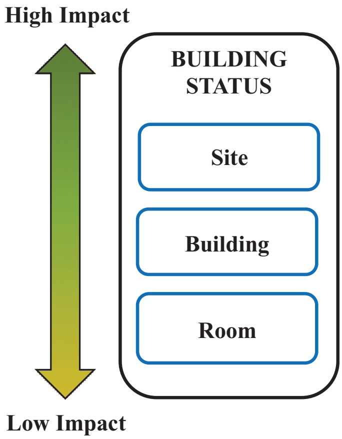

Figure 2.
Primary category, building status

"Building usage," the third category (Figure 3), represents the importance of the building function and answers how a given space contributes to an organization's overall productivity, prioritizing those spaces having a use most closely aligned with the organizations mission (Shen *et al.*, 1998; Spedding and Holmes, 1994). Prior research suggests that most real estate officers do not integrate their activities with the activities of other functional

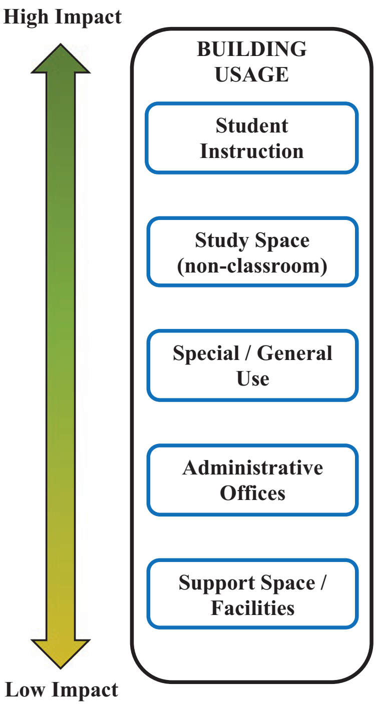

Figure 3.
Primary category, building usage

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areas (Gibler *et al.*, 2002). Therefore, this category encourages decision-makers to actively consider how a given work order will impact the function of the facility. For example, a manufacturer might prioritize the up-time of the manufacturing floor thereby maximizing operational output. Similarly, for prioritizing education, this category recognized the importance of instructional spaces over non-instructional (administrative offices, multi-purpose space, support facilities), as instructional spaces have the most significant impact on student performance (Earthman and Lemasters, 1998, 2009; Tanner, 2008). Support spaces and support facilities are assigned the lowest priority, which may include such areas as transportation yards, central storerooms, janitorial closets, utility yards or other tertiary spaces supporting the district (Cyros and Korb, 2006).

The fourth category of the decision framework leverages the findings of the literature review (step one of the methodology) to identify and categorize scholarly publications that report a relationship between facility condition and academic outcomes. Furthermore, the authors identified facility infrastructure or improvements to the existing facility infrastructure, architectural elements or building envelope shown to have a positive effect on academic climate or culture (Ariani, 2015; Bejou, 2013; Gonder and Hymes, 1994; Hines, 1996). The resulting category, "institutional enabler(s)," prioritizes the findings of the literature review according to the volume of scholarly publications (Table I). In doing so, the authors provide a method for assessing a work order based on that work orders potential impact to the building elements most often reported to benefit education.

"Enabler"	Citations (%)
Play	21
Instructional space	19
Technology zone	17
Reference space	14
Creative space	9
Comfort	5
Landscaping	4
Cafeteria	1
Lighting	1
Magnet school	1
Paint/patch	1
Room equipment and furnishings	1
Air quality	1
Circulation	1
Electrical	1
Hardware	1
Safe place	1
Visualization	1
Bathroom	0.40
Acoustic	0.27
Plumbing	0.24
Overall impression	0.17
Natural light	0.13
Temperature control	0.10
Quiet room	0.07
Activity pockets	0.05
Learning zone	0.02
Total	*100*

Table I. Academic research attributing academic performance with facility condition

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To better illustrate this structure, of the scholarly publications identified through the literature review, 17 per cent addressed technology zones and academic outcomes. This hierarchy is not claiming that completion of the work order will result in a pre-determined percentage of improvement in academic outcomes. Furthermore, the authors are not suggesting that technology zones are more significant than building systems or other building attributes cited less frequently. Instead, the structure places a value on a work order associated with technology zones based on the prevalence of academic research correlating technology zones with academic outcomes. Having identified institutional enablers specific to K-12 education, the authors then established a hierarchy aligned with a visual AHP providing facility managers a method to quickly prioritize a given work order leveraging prior research (Figure 4).

Each of the four categories as detailed in this methodology is intended to be universally applied to institutional facilities. The aim of identifying variables within each category is to provide a customizable framework that could enable the efficient prioritization of work orders while introducing to the facility operations team research-based factors that may not have otherwise been considered (Figure 5). The purpose of this research is neither to elicit 100 per cent agreement on all work orders nor to provide a comprehensive list of variables. Use of the DST is intended to create consistent relative value for the institution as it incorporates the subject matter expertise of FM, addresses the voice of the client, integrates relevant academic research and aligns with the strategic direction of the institution. In other words, identifying more elements of higher priority on the DST should guide thinking for work orders that were otherwise seemingly similar.

Scope of work. For this study and the intent of the DST, work orders defined as major repairs, including "emergency" or "critical break-fix," are out of scope and not intended to be prioritized with the aid of the DST. Response times for such work orders are of the highest priority and may, in fact, proceed without the formal documentation of a work order. The issues that constitute a major repair are defined and developed by the parent institution as a method to mitigate risk. Although the definition of a major repair is subjective according to

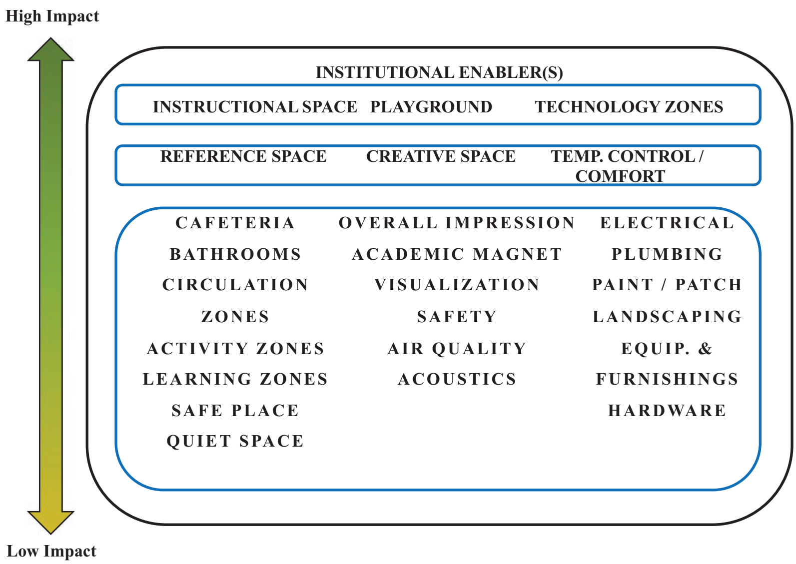

Figure 4.
Category 4, academic enablers

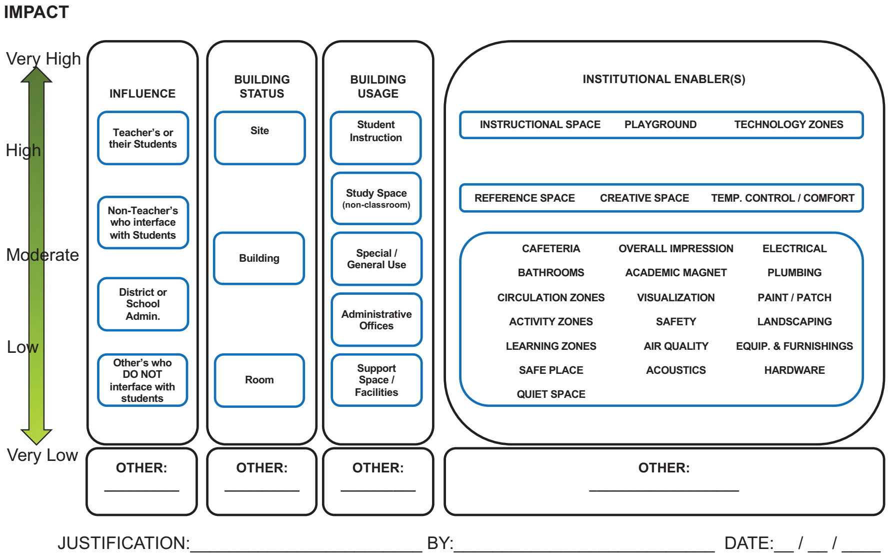

Figure 5.
DST for prioritizing routine facility maintenance, K-12 academic districts

the needs of the institution, the intent to signify a heightened sense of priority and a timely response is common in FM (Lewis and Payant, 2007). For these reasons, the DST methodology excludes emergency or critical issues, focusing instead on those work orders defined by an organization as routine or regular.

Step 4: targeted focus group

After constructing the framework, the fourth and final step was to validate whether current practitioners would understand the developed DST for prioritizing routine work. Researchers convened a targeted focus group for validating the proposed DST using a non-directed, yet controlled, discussion (Flores and Alonso, 1995). The use of a focus group was intended to provide a more in-depth perspective resulting from the interaction between the moderator and the participants (Lederman, 1990). A moderator was selected and charged with facilitating the discussion following the study's objectives. For this study, the focus group participants collectively formed a "purposive" sample of the target population, which in this case references facility maintenance personnel responsible for the prioritization of work orders (Lederman, 1990). The focus group also served a phenomenological function, sharing their perceptions and experiences specific to the prioritization of work (Moustakas, 1994).

The targeted focus group included facility maintenance and operation professionals from Arizona State University. The framework of the tool is intended to be universally applied to large-scale institutional facilities, although the research utilizes K-12 education as an area of focus. Soliciting critical feedback from the university's facility maintenance and operations staff provided a format that was both institutional in scale and transferable concerning the complexity and organizational mission. Focus group participants were understood to be SMEs in their field. The individual responsibilities of participants included those with management responsibilities to include the allocation of resources for prioritizing and completing work orders. In total, five facility administrators volunteered to participate in the targeted focus group, which utilized a snowball sampling technique (Burgess, 1984).

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Participants were asked to prioritize five example work orders representative of routine K-12 facility maintenance. The participants then responded to questions concerning the logic, viability and practical application of the DST. Discussion questions encouraged dialogue specific to the construction and functionality of the tool, such as:

Q1. How might one edit the DST to improve the ease of use and/or logic to enhance the tool making it a more intuitive experience?

Q2. What does the process of prioritizing work orders involve and what factors are considered?

Additional probing questions addressed the practical application of the DST:

Q1. Please explain how the introduction of a DST might influence resource allocation?

Q2. How might the tool align with the institution's objectives?

Focus group discussions were audio recorded for later transcription. Transcripts were coded manually using NVivo® software to produce a categorization of data, thereby expanding upon the moderator's notations to add clarity and specifics. The process of overlaying the notes and audio transcript aligns with the "note-expansion" approach enabling a more rigorous understanding of the notes (Bertrand, 1992). Transcript coding was then used to develop primary themes and learnings. Several subcategories were developed further within the themes to provide greater context.

Primary themes and learnings from the focus group were used to modify and improve the developed DST. Additionally, researchers reviewed specific recommendations or directives from the participants for constructively enhancing the tool.

Prioritizing a routine work order

In this section, routine work orders are used to explain and illustrate the implementation process of the proposed visual AHP multi-criteria decision support methodology. An initial example is provided. Then five actual work orders are prioritized by a focus group of industry professionals using the DST methodology.

Illustrative example

A routine work order is provided to better illustrate the usage of the proposed visual AHP DST (Table II). Suppose a work order was generated by an employee and must now be reviewed by an operations administrator or someone with similar responsibilities charged with the prioritization of work. According to the steps described herein, the individual

Table II.
Example of a routine work order submitted by an academic district

Work order #	OP-192029		Request date	09/25/2017 13:12
Location ID	Blue H.S. – 2SC		Completion date	
WO type	Corrective maintenance			
Description request	The flush valve in the men's restroom in the teacher's lounge is not working; it's one of those dual flush type with the green handle		Total hours	1.5
Priority description	Routine		Total cost	46.71
Item description	Item number	Item type	Task code	Task description
Men's restroom	Blue H.S. – 2SC	Area	PL11020	Inspection

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decision-maker must evaluate multiple decision alternatives using the framework of the DST as a method of categorizing and understanding each alternative.

The scope of the work order, "flush valve in the men's restroom," has a direct impact on the educational staff, male teachers (influence C_1), working within the building where the flush valve has presumably failed. It may be reasonable to expect there is more than one faculty men's restroom servicing the campus. At this point, however, it is unclear if this is the only faculty men's restroom servicing the building (building status C_2). Restrooms are not considered to be "instructional spaces," nor would the restroom be "administrative." Therefore, the function of the men's restroom, building usage C_3, can be defined as "special/general use." Within this category, and specific to K-12 education, the term "special/general use" may apply to such areas as administrative offices, restrooms, multi-purpose rooms or similar tertiary spaces available to faculty, students and staff supporting the primary function of the institution (Cyros and Korb, 2006).

The fourth category in the DST (institutional enabler C_4) includes those factors identified through a comprehensive literature review that meet the criteria of the filters and thus imply a relationship between academic performance and facility condition. Here the DST leverages the professional experience of the facility manager given the work order may address "plumbing" as a building system and "bathroom" as a quality of the campus.

In summary, completing the DST and prioritizing the work accordingly may result in a visual assessment of "moderate" to "high" given the aggregate score of each of the four categories (Figure 6). In practice, however, the tool requires the input of the facility manager to be successful. For example, specific to this work order, the building may have multiple men's restrooms, there may be no male employees at this school, or the leak may simply be overstated given the experience of the service technician. Regardless, the DST methodology requires both a subjective and objective assessment of the work order to appropriately prioritize the work.

Findings and discussion

To verify the effectiveness of the proposed DST, work orders representing routine facility maintenance at a K-12 district were presented to the focus group. For comparison purposes,

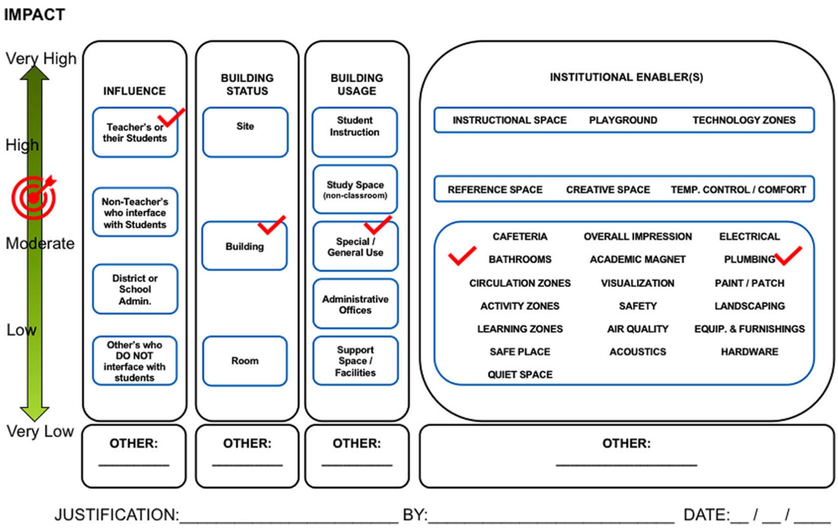

Figure 6.
Example of multi-criteria decision-making using the DST

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all work orders were obtained from a participating academic district and provided to the focus group with limited edits to anonymize the source of the original work orders. The focus group included five facility managers responsible for decision-making concerning routine facility maintenance and repair. The participants of the focus group FG_P ($P = 1, \ldots, 5$) were asked to evaluate five work orders WO_n ($n = 1, \ldots, 5$) using the four categories as presented in the DST, where C_1 represents "influence," C_2 represents "building status," C_3 represents "building usage" and C_4 represents "institutional enabler."

The prioritization activity was purposefully designed to familiarize the participants with each of the four categories, introducing the variables within each category. Work order "1" was intended to be understood as a "very high" priority work order, given the scope of work and by virtue that all four categories should theoretically be marked as such on the DST. In contrast, work order "2" was purposefully selected as "very low," again reflecting the intent of the DST. Work order "3" addressed a fire sprinkler system and was intended to be identified as an "emergency" repair and thereby omitted from the results. According to the methodology, matters of fire/life safety are deemed emergency and of the highest priority. The objective of the DST is to prioritize those work orders that may be categorized as routine and prioritized subjectively at the discretion of the institution. The observed results indicate the DST was effectively used and understood by the participants, without requiring clarification by the researchers. Participants were quickly able to translate the scope of work, as documented in the work order, to the DST format. At this stage in the research, the order of prioritization is subordinate to the process of using the DST. The findings suggest the DST successfully functioned as a usable and efficient method for prioritizing work orders.

Having completed the prioritization exercise, researchers asked a series of qualitative questions intended to solicit constructive dialog within the focus group. According to the panel, the format and process of completing the DST were understood to be intuitive and user-friendly. Once the method of evaluating the visual AHP was understood, participants estimated the time to complete a DST specific to a given work order, would "not add more than 15 seconds to the process." The focus group did express reservations, however, with the volume of work orders entered into the asset management system and that point at which the DST would become a burden on the system administrator or functional area lead tasked with prioritizing work orders. While this feedback makes sense from a practical perspective, it seems to highlight the underlying motivation for why a DST would be necessary with such a plethora of work orders to handle. Furthermore, when considering the types of tasks necessary to schedule a work order currently, the estimated 15 additional seconds to complete this DST may not be unreasonable if it were to be broadly implemented.

The focus group agreed on the four primary categories of influence, building status, building usage and institutional enablers to accurately frame the scope and responsibilities of a FM operation. Moreover, the focus group recognized the importance of modifying the DST according to the needs of an institution while preserving the overall structure of the tool as significant. In doing so, the transferability of the tool resonated with the focus group and was generally understood to be of benefit. Furthermore, the simplicity of the design was recognized to be a positive attribute, adding to the transferability of the tool. One participant noted "I like the simplicity," expressing that as an institutional facility becomes more complicated the tendency of the technician is to complicate the prioritization of the work orders in the queue. The DSTs framework encourages the technician to simplify the process, resulting in a more objective assessment of the work order.

The findings from the purposive focus group suggest that while the DST is transferable between institutional facilities, the subcategories or determinants within each category are dependent on the nature and function of the institution. While this limits the transferability

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of the specific DST developed by the authors, it provides further validation to the DST process development defined in this paper (i.e. steps 1-3), which require future researchers to first identify or define institutional enablers that are appropriate to a new type of institution. As the needs and characteristics of an organization are unique identifiers, so too are the forces which govern the prioritization of work.

The allocation of resources and ultimately the prioritization of work are likely to be influenced by the function of the institution, geographic layout of the building infrastructure, the complexity of the building systems and the personal experience or ability of the technician charged with prioritizing work. While this might initially seem like a limitation for a DST to rely partly on potentially subjective judgments of technicians, this approach also allows for considerations related to the context of a specific work order that may be nuanced and not directly considered by the previous research findings, which are incorporated into the DST. There are, in fact, many competing variables that factor into the prioritization of work. The involvement of human judgment in this process may help to handle qualitative assessments that a strictly quantitative approach might incorrectly assess.

Limitation

The objective of this paper is to propose a methodology illustrating the process and development of a DST for the prioritization of routine facility maintenance. Although the results suggest the process can successfully lead to a DST that is understood by practitioners, the authors cannot at this time claim the extent to which the proposed DST influences the decision-making process.

A working prototype of the DST, built upon the results of this study and in cooperation with facility maintenance and operations SMEs, will be developed to serve as a basis for a counterbalance measures assessment. This next phase of research will: A) validate the prototype DSTs ability to standardize the prioritization of work and B) assess the ability of the tool to influence the end users thought process when prioritizing routine facility maintenance requests.

Conclusion

In this paper, authors propose a visual multi-criteria methodology for the prioritization of routine institutional facility maintenance. Regarding initial focus group testing results, it is clear that when using differing work orders and the proposed structure of four primary categories, the proposed visual AHP methodology can effectively be used and understood to prioritize multi-criteria work orders. Furthermore, this process can support the development of a DST that is simple to use and may offer value for practical implementation by organizations in the future. The findings documented in this paper suggest that the proposed visual AHP multi-criteria methodology has a potential application for the prioritization of routine institutional facility maintenance. The contribution of this paper is in providing a reusable methodology that aims to coalesce the findings of disparate research findings into an easy-to-use DST that allows practitioners to make evidence-based spending decisions about routine facility maintenance to improve overall institutional performance.

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