AN AUTOMATED VALUE-BASED EVALUATION AND CONDITIONAL APPROVAL OF CONSTRUCTION SUBMITTALS

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Abstract. To ensure compliance with specifications during construction, a formal review process, called the submittals process, is typically used whereby a contractor submits proposals for materials, equipment, and processes for owner’s approval. This evaluation process can be a difficult task because of time restriction, lack of information in the submittal package, and lack of defined criteria for evaluation. This study thus introduces an automated decision support for submittal evaluation that uses the Multi-Attribute Utility Theory (MAUT) to evaluate a submittal considering its impact on the construction and operation of the building. First, key building submittals are analyzed and the top one (chiller) is selected and its evaluation parameters grouped into two categories: non-flexible and flexible. The non-flexible parameters have been dealt with as a checklist with predefined thresholds that must be met without tolerance. Flexible parameters, on the other hand, have been analyzed using utility values that represent decision makers’ preferences and tolerance levels. Accordingly, the evaluation process determines the overall utility for the submittal and the value-based condition for accepting it. An automated prototype system has been developed using data provided by three organizations through intensive interviews with experts. A case study was then used to prove that the proposed evaluation system provides consistent and objective decisions, internal alignment of organizational values, and improved lifecycle performance of submittal items.

1. Introduction

The accuracy of specifications is crucial to successful construction and operation of buildings. Designers, however, often provide rough specifications based on limited details, previous specifications, readily available standards, and/or experience (Emmitt 2001). Such practice simply postpones liability and problems to the construction stage (Kululanga and Price 2005), during which frequent changes in the specifications will occur due to construction conditions and product/material availabilities. The final as-built specifications for many building components and their actual operational characteristics are therefore finalized only during the construction phase (Friedlander 2000). Accordingly, reviewing all products prior to installation is essential for conformance to specifications (Ingold 2010; Drake 2002). Such a review is conducted through the submittal of detailed information about
the product/item so that the owner can make a wise decision about the adequacy of the item in question (Hinze 1993). This submittal process requires the contractor to submit a proposal for all materials, equipment, and processes, based on the design specification, for owner’s approval before they can be used or installed on site. Evaluating the submittal during the ongoing construction work can be a difficult task because of time constraints, information missing from the submittal package (Atkins 2006; Liescheidt 2003; Scott 1996), difficulties in retrieving related information from text and CAD files (Wood 1996), and the lack of defined criteria for the evaluation which led to unsatisfactory experience based decisions. The submittal process connects the design requirements to the construction details that are needed for constructing the project by providing all information that becomes known only during construction stage and reflecting the manufacturer data (Schinnerer 2003; Drake 2002). The data approved in the submittal will also be a new reference values for the commissioning and testing procedure, which, as a result, may require modification before the project is turned over to the operation team (TURKASLAN-BULBUL 2006). Seemingly minor changes can affect performance and have implications not only for construction but also for the operation of the project.

The primary objective of this research is to develop an automated value-based framework that can support the evaluation of construction submittals and that takes into consideration the impact of changes in the specifications on the operational characteristics of a building. Evaluation results provide total score value for each submittal or alternative determining it acceptability. Only when the score is within the acceptable range, submittal is considered and penalty is calculated developing approval condition.

2. Background and Related Research

2.1. RESEARCH TO AUTOMATE SPECIFICATION

Several research efforts have focused on automating specification development and code checking. For evaluating compliance with building codes, the Extended Building Code (EBC) has proposed a new framework that integrates code checking and performance analysis for a building envelope using decision tables (Tan et al. 2007). Horvat (2005) used the Extended Building Code to evaluate the performance of a light-frame building envelope using Microsoft Excel. Singapore’s e-plan checking project, The COnstruction Real Estate NETwork (CORENET), allows Architecture/Engineering/Construction (AEC) professionals to submit project plans and documents online for review. An interesting system for automating the preparation, checking, and updating of specifications was introduced commercially as e-SPECS, which is an online software program that is integrated with the Building Information Model (BIM).

2.2. TOOLS FOR MANAGING SUBMITTALS

The increasing effort in the industry to control submittals has become apparent. Several computerized systems are available independently or as a part of construction document management system such as, Attolist, Vico, BuildSite, SUBMIT, Newforma, AccuBuild, and Submittal Exchange. All systems are available online to track submittals considering manual submittal evaluation, thus dealing with submittals from a document management perspective only.
Collaborative efforts among the National Institute of Building Science’s (NIBS) Facility Maintenance and Operation Committee, the Facility Information Council (FIC), the International Alliance for Interoperability (IAI), and the National Building Information Model Standard (NBIMS), have initiated the Construction Operation Building Information Exchange (COBIE) project for facilitating data exchange between the construction and operation stages. The main objective of COBIE is to enhance the capturing of information during the design and construction stages and then transfer it for operation and maintenance purposes. A submittal for COBIE is the natural way of collecting updated data about equipment, products, and materials; the approved submittal reflects the final data. COBIE provides a standardized data structure for submittals (Brodt 2006; East 2007).

3. Analysis of Key Building Submittals

3.1. DATA COLLECTION

The data collection process involved three public organizations and a consultant office. The collected data included historical submittal packages and submittal logs, and general specification guidelines. The collected data were then analyzed in detail to define the initial top key submittals list. Each submittal package includes the submittal form filled by the contractor with a description of the submitted item; with the bottom part showing the consultant's decision (approved, approved as noted, disapproved, or no action). A submittal form can be used to evaluate more than one alternative for a single item, in which case, the decision for each alternative is recorded in the appropriate place.

A variety of submittal packages from all building disciplines were collected and 653 were analyzed. Out of the 154 mechanical submittals, 89 were approved during the first round while 65 were rejected or required resubmitting. The HAVC system exhibits the highest number of rejected/resubmitted items (59 %).

The collected submittal logs mainly indicate the date IN and OUT for the submittals and the action that was taken for each one. An analysis of a log with 136 submittals for a sample project provided by an organization in Toronto, Canada in February 2009 showed that the average processing time for the first evaluation round was about 34 days. It was expected that the second round (resubmission process) would take less processing time, but the average for the second round was almost the same as for the first.

An interesting submittal log entitled "Long Lead Material Submittal Schedule" was also analyzed. A unique log such as this one gives an indication of the process used for critical material/equipment items in construction. A review of this log shows that it covers only three disciplines: architecture, mechanical, and electrical. The majority of items are architectural (63 %), while the mechanical items represent only 25 %, and the electrical items make up the remaining 12 %. Within the mechanical category, 75 % of the items are HVAC components.

3.2. IDENTIFYING KEY SUBMITTAL

To identify the key submittals, a process started with historical collected data analysis and involving interviews with experts in addition to a comprehensive literature review. The participated experts were selected based on their experience in the field; it has been considered to have at least 15 years of experiences in construction management, reviewing submittals, and directing approval process. They all showed full cooperation, access to files,
and devoted time for meetings in order to review and discuss the list of long lead material submittals and the analysis of the collected data. The objective was to identify the top 10 key submittals.

According to literature and the analysis of collected data, an initial list was developed and ranked, as shown in the 1st column in “Table 1”. During the interviews with the experts, critical considerations were discussed, and it was determined that an item can be considered critical when:
1. manufactured away from the project site (overseas),
2. requires customization by a specialized party,
3. dealership/support is far from project location, which affects repair time,
4. requires a designated space and installation process, or
5. has many successors in the construction schedule.

These considerations apply most to major building equipment, which involves technical drawings that must be reviewed, items that must be outsourced and procured, customization, dedicated space, an installation process, and testing and commissioning, and affect the time needed for evaluating submittals. Based on the criticality considerations and considering the impact on operation, an initial list of key submittals was developed and discussed with experts to obtain the final list. The feedback from the experts was obtained in a form of ranking for the initial list in order to have the average rank value for each item in the initial key submittals as shown in Table 1. Last column in Table 1 shows the final rank for the items where the top ten is in bold.

Since the chiller is the top-ranked submittal item identified in this research, it was further analyzed to develop a decision support system that would facilitate the evaluation of this key submittal item.

### 4. Proposed Submittal Evaluation Mechanism

An analysis of the chiller parameters revealed that they could be divided into two sets: flexible and non-flexible. The non-flexible parameters require the submitted item to match the requirements exactly; otherwise, the item will be disapproved. The non-flexible parameters thus lend themselves to a checklist type for speedy evaluation. Any violation of the checklist threshold values means rejection of the item. The second set of evaluation criteria is the flexible parameters, i.e., ones with a range of acceptable values. It is possible to receive submittal items that offer different degrees of satisfying the requirements. Different submittals also might have different levels of effect on building performance, other equipment and/or resources, energy consumption, construction needs, or operation. The weights of these parameters can vary between organizations and even between different projects.

#### 4.1. COMPLIANCE CHECKLIST WITH NON-FLEXIBLE PARAMETERS

For a chiller, a compliance checklist was developed based on interviews with experts from the collaborating organizations. The interviews that discussed the applicability of each of chiller parameter as a checklist parameter, shows minor differences among the experts with respect to the selection of checklist parameters. A default checklist (Table 2) was therefore determined based on their feedback. This list will always be initially available in the
evaluation system, and any organization can modify it to suit specific needs. The default checklist was then ready for pre-screening stage.

<table>
<thead>
<tr>
<th>Initial List of Key Submittals</th>
<th>Expert M Rank</th>
<th>Expert R Rank</th>
<th>Expert Y Rank</th>
<th>Expert A Rank</th>
<th>Average Score</th>
<th>Final Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chiller</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1.0</td>
<td>1</td>
</tr>
<tr>
<td>Boiler</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>2.5</td>
<td>2</td>
</tr>
<tr>
<td>Electrical Panel Board</td>
<td>5</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>12.5</td>
<td>12</td>
</tr>
<tr>
<td>Fan Coil Unit</td>
<td>15</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>6.25</td>
<td>8</td>
</tr>
<tr>
<td>Package Unit</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td>Fume Extract System</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td>Air-Handling Unit</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3.3</td>
<td>3</td>
</tr>
<tr>
<td>Exhaustion/Ventilation Fans</td>
<td>4</td>
<td>7</td>
<td>6</td>
<td>3</td>
<td>5.0</td>
<td>4</td>
</tr>
<tr>
<td>Motor control center</td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>5.8</td>
<td>6</td>
</tr>
<tr>
<td>Building Automation System</td>
<td>7</td>
<td>15</td>
<td>7</td>
<td>15</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>Security/Access System</td>
<td>9</td>
<td>15</td>
<td>10</td>
<td>15</td>
<td>12.25</td>
<td>11</td>
</tr>
<tr>
<td>Lighting Fixtures/Type</td>
<td>8</td>
<td>9</td>
<td>8</td>
<td>10</td>
<td>8.8</td>
<td>9</td>
</tr>
<tr>
<td>Sound Address System</td>
<td>10</td>
<td>15</td>
<td>11</td>
<td>15</td>
<td>12.75</td>
<td>13</td>
</tr>
<tr>
<td>Cooling Tower</td>
<td>15</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>5.5</td>
<td>5</td>
</tr>
<tr>
<td>Pump</td>
<td>11</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>6.0</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 2: Default Checklist for Non-Flexible Parameters

<table>
<thead>
<tr>
<th>S Parameters</th>
<th>Acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Compressor Type</td>
<td>Same as specification</td>
</tr>
<tr>
<td>2 Chiller Type</td>
<td>Same as specification</td>
</tr>
<tr>
<td>3 Motor Type</td>
<td>Same as specification</td>
</tr>
<tr>
<td>4 Flow Rate (GPM)</td>
<td>Same as specification</td>
</tr>
<tr>
<td>5 Starter Type</td>
<td>Same as specification</td>
</tr>
<tr>
<td>6 Service Requirement</td>
<td>No additional equipment</td>
</tr>
<tr>
<td>7 Water Inlet Temperature</td>
<td>Same as specification</td>
</tr>
<tr>
<td>8 Water Outlet Temperature</td>
<td>Same as specification</td>
</tr>
<tr>
<td>9 Dimension/Weight</td>
<td>As in shop drawing</td>
</tr>
<tr>
<td>10 Pressure Drop</td>
<td>&lt; Pump Capacity</td>
</tr>
</tbody>
</table>

For a submittal or alternative \( i \) to pass the prescreening stage, every parameter \( V_{ij} \) must receive a "pass" at this stage.

4.2. EVALUATION OF FLEXIBLE PARAMETERS

Once a submittal passes the pre-screening step (checklist), it then undergoes a detailed evaluation based on a set of flexible parameters. These flexible parameters are the evaluation criteria for the selected item. To develop the criteria, chiller parameters discussed again with
the experts to set the list of criteria. Each organization was approached independently in order to develop the criteria and their weights. The constraints that each organization may have with respect to a project determine their decision in regard to any minor change in the values. The basis for rating criteria was the impact of the change on resource consumption, on the maintenance schedule, and on the user productivity. Based on the feedback, criteria were developed as presented in Table 3, 1st column “Criteria”. The interview with the experts was extended in order to assign weights to these criteria that would reflect the importance of each one for the organization. Table 3 presents these weights listed by organization. While in this research the average weight is taken, in real life, each organization shall use this average weight as reference to set their own weights according to their preferences and the importance of each criteria, project, and organization needs.

Table 3: Weights Assigned to Criteria by Participating Experts

<table>
<thead>
<tr>
<th>#</th>
<th>Criteria</th>
<th>Organization 1 Weights (Σ = 100%)</th>
<th>Organization 2 Weights (Σ = 100%)</th>
<th>Organization 3 Weights (Σ = 100%)</th>
<th>Average Weights (Σ = 100%)</th>
<th>Final Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Power Consumption</td>
<td>32</td>
<td>55</td>
<td>41</td>
<td>42%</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Technical Support</td>
<td>23</td>
<td>7</td>
<td>8</td>
<td>13%</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Refrigerant Type</td>
<td>15</td>
<td>13</td>
<td>29</td>
<td>19%</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Condenser Water-Box Type</td>
<td>11</td>
<td>8</td>
<td>NA</td>
<td>6%</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>Condenser Tubes Thickness/Material</td>
<td>11</td>
<td>NA</td>
<td>18</td>
<td>10%</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>Sound Level</td>
<td>8</td>
<td>17</td>
<td>4</td>
<td>10%</td>
<td>4</td>
</tr>
</tbody>
</table>

4.3. UTILITY FUNCTIONS AND CALCULATION METHOD

The overall score and calculation method for a criterion provides a quantitative measure of any minor change in the submittal. Such measures can reflect the impact on operation (energy), maintenance costs, and owner/organization satisfaction. To establish quantitative measures, multiple attribute utility functions (MAUT) theory was used for the value-based criteria evaluation. The acceptability of the values submitted in the MAUT is limited to a specific range that can be changed based on the requirements of the organization or owner. The utility value of each parameter submitted for a criterion can vary from one organization to another and is limited to their approved range of acceptability. For each default criterion, the organizational constraints are used, and the most general values are considered as the default. The values for multiple intervals within the criterion generate a utility function graph. The shape of the graph, that is, whether to be risk-seeking, risk-adverse, or risk-indifferent, is also determined based on the organizational constraints. The score for each criterion \( j \) is the utility value \( U_j \) of the contractor-submitted value multiplied by the weight \( W_j \). The overall score value for the submittal or alternative \( i \), \( S_i \), reflects the owner satisfaction and is the sum of all criteria scores, given by

\[
S_i = \sum_{j=1}^{n} W_j U_j \quad i = 1, 2, 3, ..., n
\]
Such a score has a minimum acceptable value that is determined by the organization based on the project criticality. A submittal or alternative is rejected when its score is less than that required.

In addition to calculating the overall score $S_i$ for submittal alternative $i$, it is also important to calculate the cost $A_i$ of using this submittal. This cost includes the operational cost, the maintenance cost, the additional construction cost, and any other cost related to the submittal. These can be evaluated by evaluating the criteria one by one and calculating any related cost. Accordingly, the cost of using submittal $A_i$ then becomes

$$A_i = \sum_{j=1}^{n} C_{ij} - R_i$$

where $C_{ij}$ is the cost of submittal $i$ in criterion $j$, and $R_i$ is the cost of the original required item with respect to the same criteria. This $A_i$ cost, therefore, should be considered as a penalty or condition for reducing the item price by this value. In addition, a total penalty $P_i$ can also be calculated by adding any reductions in the satisfaction of the evaluation criteria, as follows:

$$\text{Total Penalty } P_i = A_i + (100 - S_i) \times A_i/100$$

As presented in the following, the default criteria were investigated one by one both in the literature and at the organizational level in order to set up the default method for calculating the extra cost and for developing a utility function for each criterion.

5. The Automated Submittal Evaluation System

The checklist, criteria, and MAUT calculations mechanism for the selected key item that are developed and that have been presented previously were coded in an Excel spreadsheet in order to automate the generation of quantitative value (utility value) for a submitted key item. These coded spreadsheets use VBA programming language to develop the main prototype, SUBMIT & EVALUATE, considering any number of criteria and is coded to perform all necessary calculations and to generate reports.

The evaluation system prototype is presented through processing a real-life case against the default requirements of checklist and criteria. The real-life case (submittal) for a chiller, the key item, collected from a Canadian organization, which has deviations from the required specification because of unavailability of the required specified item at the time of construction. The deviations were in criteria as it will be shown in the illustration.

The contractor submitted data populates the EXCEL spreadsheets based on which the actual evaluation process is performed. All parameters matched the checklist requirements and as result the alternative has been granted “PASS” status as shown in Figure 1. By passing the checklist stage, the system moved the alternative to the next evaluation stage: value-based evaluation.
The value based evaluation considers evaluating the criteria submitted values against the default acceptable range of each criterion that gives utility value for each. Figure 2 shows screenshot for where contractor data is populated. The calculations are processed for each criterion using the built-in equations and developed utility function graphs to provide the score and direct cost of each criterion. Each criterion is explained in order to demonstrate the automated evaluation system and shows the automatic generated utility value and cost.
CRITERION 1: POWER CONSUMPTION

The submitted power input value has been applied automatically to the utility function graph that generates the utility value. The score for the criterion is then derived from the multiplication of the utility value by the weight, as shown in Figure 3.

The extra cost noted in Figure 3 is a result of the equations that consider the present value of the operation impact of the minor noted change on power consumption. The two values that are extracted for the power consumption criterion are the extra cost ($4,219) and the total score for the criterion (41.5).

CRITERION 2: REFRIGERANT TYPE

The default required refrigerant is R-134a while the submitted type is R-123, which is given a utility value of 70. Changing from R-134a that is 100% to R-123 that is 90% in satisfaction value for the organization costs a figure of $50,000. Based on the derived utility value, the final score for the criterion is 17 out of 19 as shown in figure 4, which presents the final score and the extra cost.

CRITERION 3: TECHNICAL CAPABILITIES

The default for technical capabilities is company 1, with a utility value of 90. The value of these companies was determined in referring to the participated organization history
with each company. None of them receive the 100% satisfaction. It is considered that there is no change in the submittal value in regard to this criterion, so it receives the maximum possible score: 11.7, representing less satisfaction without any direct cost. (Figure 5)

CRITERION 4: CONDENSER TUBES THICKNESS AND MATERIAL

The default tube type is the copper nickel tube with the thickness of 0.035” while the submitted one having the same material but with a thickness of 0.028”, which is allocated a utility value of only 66.7, producing a total score of 6.67. Figure 6 shows the EXCEL sheet for this criterion, from which the utility value is generated. The calculation for each session for tube cleaning assumes having one HVAC technician and two HVAC assistant laborers to work an average of 40 hours in each session. Based on the hourly rates of $19/hour for the HVAC technician and $14/hour for the HVAC service technician as per the website (www.indeed.com) the cost of each tube cleaning session came to $2,068.0. Using an interest rate of 11% and a lifecycle of 25 years, the extra cost is then $14,876.38 (Figure 6). It should be noted that this criterion is affected by the selected water-box type since NIH (Nussle in Hole) water-box increases the required maintenance time. Water-box type as criterion will be evaluated in this process as a sixth criterion.

CRITERION 5: SOUND LEVEL

The submittal data do not include the Sound Pressure Level data because the manufacturer for the chillier was contacted, but there was no response. The value used for the submittal is therefore the minimum value according to the ARI 575 standard. As shown in Figure 7, the
submitted and minimum curves are perfectly aligned, which reflects a 100% satisfaction level and results in a score of 10.

**Figure 6. Sound Level Page within the Prototype**

**CRITERION 6: CONDENSER WATER-BOX TYPE**

The water-box parameter in the submittal data matches the 100% default option, which is the marine. Figure 8 presents the utility function graph for the three options available to the contractor where the change between water-box types affects the maintenance during chillier lifecycle. The utility value for the marine is 100%, which results in a final score of 6, according to the weight.

**Figure 7. Condenser Water Box Type Utility Value, Score, and Cost**

The condenser water-box type evaluation conclude the criteria evaluation and all scores and direct costs are then inserted automatically in the correct cell so that the final submittal score and condition, if any, is calculated. Figure 9 presents the approval status, total score, and the condition value as a result of the data compiled and calculated; these are the results presented to the decision maker/project manager or contractor. In addition to these results, a report indicating the details of the score and the direct cost is provided to them (Figure 10). In this case, the final score for this submittal is 89.12 and the total compensation/penalty value is $76,610.73. This total is a summation of total direct costs that is 60,095.86, and the impact score on satisfaction that is $7,514.87. They are represented in the report (Figure 10).
The alternative can then be finally approved or not depending on if the score is above or below a minimum acceptable threshold (default) set by the organization. If the score is above the minimum acceptable threshold, the contractor then must compensate the owner with the cost as condition to finalize the approval.

6. Validation

The results of the presented evaluation system has been validated by running several historical real-time cases in the system and compared to the decision given at the time of construction where it found to be matched to the proven to be the best alternative/decision and adding subjective and quantitative value for the alteration provided by the contractor during the submittal time. The following table (Table 4) presents the results of three real-time cases processed by the developed system and compares them to manual real-time decision for validation and as a part of the validation carried for the developed framework.

7. Future Work

Various improvements are currently being planned for the proposed system, including:

- Implement the prototype on a web site for remote access to allow contractors to self-evaluate potential submittals;
- Integrate the system with existing building information modeling (BIM) tools to facilitate the storing and retrieval of specification data. BIM will ensure the automatic transfer of the most updated information, including organizational and lifespan data, directly into the submittal evaluation system;
- Transfer updated system performance data to the operating stage to facilitate effective operation and maintenance;
- Analyze the requirements for other key building submittals;
- Link the system to manufacturers’ databases in order to automatically retrieve updated specifications and parameters for the items under evaluation; and
- Consider propagating the changes for any item to other related items. Changes in the HVAC system, for example, may mandate the selection of a different class of windows in order to capture more sunlight.

<table>
<thead>
<tr>
<th>Real-time Decision/Approval Status</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approved</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conditional</td>
<td></td>
<td>Rejected</td>
<td></td>
</tr>
<tr>
<td>Conditional</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Approval Status</th>
<th>Case Score</th>
<th>Approval Condition</th>
<th>Reasons for decision:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case Score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>77.28 of 100</td>
<td></td>
<td>$78,936.23</td>
<td>Power input less than required and Cooling Capacity higher than required</td>
</tr>
<tr>
<td>77.24 of 100</td>
<td></td>
<td>$77,412.39</td>
<td>Power input less than required - Service support for supplier is rated as 80%</td>
</tr>
</tbody>
</table>

8. Conclusion

This research developed an automated value-based evaluation framework for conditional approval of construction submittals utilizing the multi-attribute utility theory (MAUT). For any key submittal, defining a generic set of criteria is difficult since each organization has its own preferences that must be incorporated into the decision process. The framework's unique feature of determining a monetary penalty value as a condition for accepting a submittal was particularly interesting to the experts. In this value-base evaluation, some experts welcomed the ability to save money on that item and use it as contingency in the project. In summary, it has been demonstrated that an automated value-based evaluation of construction submittals provides numerous benefits: an expedited decision process, an audit trail for decisions, more consistent and objective decisions, internal alignment of organizational values, and improved lifecycle performance of buildings. These benefits were validated through case study application and experts' evaluations.

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SECTION THREE: DIGITAL TOOLS IN DESIGN AND CONSTRUCTION