Real Time Quality Assurance Indexes for the Residential Houses Construction Processes

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Introduction

Motivation
• Quality control gets more and more important in construction industry.
• Small and medium enterprises (SMEs) are the most active players in the residential houses sector: problems to build up a quality system (too expensive and time-consuming).

Project QuCon
• EU-project “Development of a Real Time Quality Support System for the Houses Construction Industry” (QuCon).
(Partners are from Germany, Cyprus)

Quality Model in QuCon

Algorithms is developed with respect to Quality Model.
Availability is the Overall Quality Assurance Index!

Real Time Quality Assurance Indexes

Basic Idea
• Quality control in construction industry is realized by site inspection, time of the inspections can be defined as Checkpoints (critical points, yellow box in figure)
• Determine the scores (=availability) and weightings of the Checkpoints
• Determine the Real Time Quality Assurance Indexes as the weighted mean of the scores of Checkpoints (example)

Two problems to be solved:
1. Weightings of Checkpoints
2. Scores of Checkpoints

- \( w_j \) is the weighting for Checkpoint \( j \),
- \( s_j \) is the score for Checkpoint \( j \),
- \( J \) is the total number of the Checkpoints up to this point of time.
Crafts, Check Items, Checkpoints

- **Crafts**: Task groups (e.g., structural, electrical, sanitary, painting work etc.)
- **Check Items**: For the quality control of different crafts, there are checklists, that contain many check items, which should be checked by inspector (contracts, standards, literature etc.)
- **Checkpoints**: Time of the site inspection during the construction processes, One Checkpoint can contain check items that belong to different crafts

### Weighting of Checkpoints

1. Define the weightings of crafts (e.g., according to cost)
2. Determine the weightings of check items
3. Determine the weightings of Checkpoints

<table>
<thead>
<tr>
<th>Crafts No.</th>
<th>Crafts</th>
<th>Crafts Weightings</th>
<th>Number of Check Items</th>
<th>Check Items Weightings%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Earthwork</td>
<td>3.6</td>
<td>6</td>
<td>0.6</td>
</tr>
<tr>
<td>2</td>
<td>Structural Work</td>
<td>31.2</td>
<td>63</td>
<td>0.4952</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>6</td>
<td>Electrical Work</td>
<td>3.8</td>
<td>14</td>
<td>0.2714</td>
</tr>
<tr>
<td>7</td>
<td>Heating and Sanitary Work</td>
<td>12.9</td>
<td>40</td>
<td>0.3225</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>17</td>
<td>Floor Covering</td>
<td>4.2</td>
<td>6</td>
<td>0.7000</td>
</tr>
</tbody>
</table>

\[
W_{\text{checkpoint for excavation}} = 6 \cdot 0.6\% + 4 \cdot 0.4952\% = 5.58\%
\]

**The 1. Problem: Weightings of Checkpoints is solved!**
Real Time Quality Assurance Indexes

Scoring of Checkpoints

**Scoring System of Checkpoint**

- **Step 1:** Classify and scoring of check items and input planned and actual expense and time
- **Step 2:** Scoring of product- and process-related quality characteristics
- **Step 3:** Determination of overall quality indexes

**Scoring of Checkpoints**

- Classify the check items to: for completeness, for correctness, and for accuracy (only for the high-precise)
- The $S_{\text{com}}$, $S_{\text{cor}}$, and $S_{\text{acc}}$ are the scores of product quality, they are weighted mean of the according check items, they are between 1 and 5*  

$$S_{\text{com}} = \frac{\sum W_{\text{com},i} \cdot S_{\text{com},i}}{\sum W_{\text{com},i}}$$

$$S_{\text{cor}} = \frac{\sum W_{\text{cor},i} \cdot S_{\text{cor},i}}{\sum W_{\text{cor},i}}$$

$$S_{\text{acc}} = \frac{\sum W_{\text{acc},i} \cdot S_{\text{acc},i}}{\sum W_{\text{acc},i}}$$

*1 represents fail, 2 is the threshold, 5 is maximum score, 3 and 4 will have a check-specific range of values
Real Time Quality Assurance Indexes

**Scoring of Checkpoints**

Scoring of **Process-related** Quality Characteristics by comparing the actual and planned expense and time

\[ S_{\text{exp}}^j = \frac{E_j^1}{E_j^0} \quad S_{\text{time}}^j = \frac{T_j^1}{T_j^0} \]

- \( E_j^1 \) is the actual expense and \( E_j^0 \) is the budget between checkpoint \( j-1 \) and \( j \)
- \( T_j^1 \) is the actual time consumption and \( T_j^0 \) is the planned time consumption between checkpoint \( j-1 \) and \( j \)
- In this way, the \( S_{\text{exp}}^j \) and \( S_{\text{time}}^j \) should be **around 1**. The bigger they are the better is the quality.

**Weighting**

\[ W_{\text{com}}^j, W_{\text{cor}}^j, W_{\text{acc}}^j, W_{\text{exp}}^j, W_{\text{time}}^j \]

The 2. Problem: Score of Checkpoints is solved!

\[ Q_j = \frac{\sum_{j=1}^{n} W_j \cdot S_j}{\sum_{j=1}^{n} W_j} \]
Summary

By using the checkpoints and scoring system, the reasonable and necessary action can be carried out, the quality of the construction can be improved and assured in real time.

Conclusion and Outlook

- An application-oriented Quality Model for the residential houses is defined.
- The algorithms of real time quality assurance indexes is developed with respect to this Quality Model.
- The research results is implemented in a web-based software, the prototype is ready-to-use.
- Checkpoints, check items, weighting system should be upgraded by feedback from the end users.
- The developed QuCon scoring system is not restricted on residential houses. (Application to other construction processes: high-building, road construction etc.)
Thank you very much for your attention!

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Real Time Quality Assurance Indexes

Scoring of Checkpoints

Scoring of process/ product/ Overall Quality Indexes

• One Score for Product Quality:

\[ S_{\text{product}} = \frac{S_{\text{product}}^\text{exp}}{5} \cdot \frac{W_{\text{product}}}{W_{\text{product}} + W_{\text{cor}} + W_{\text{acc}}} \times \frac{S_{\text{product}}^\text{cor}}{5} \cdot \frac{W_{\text{product}}}{W_{\text{product}} + W_{\text{cor}} + W_{\text{acc}}} + \frac{S_{\text{product}}^\text{acc}}{5} \cdot \frac{W_{\text{product}}}{W_{\text{product}} + W_{\text{cor}} + W_{\text{acc}}} \]

Weighting:

\[ W_{\text{product}} = \frac{\sum_{i=1}^{N_{\text{product}}} W_{\text{product}}^i}{\sum_{i=1}^{N_{\text{product}}} W_{\text{product}}^i + \sum_{i=1}^{N_{\text{cor}}} W_{\text{cor}}^i + \sum_{i=1}^{N_{\text{acc}}} W_{\text{acc}}^i} \]

• One Score for Process Quality:

\[ S_{\text{process}} = \frac{S_{\text{process}}^\text{exp}}{5} \cdot \frac{W_{\text{process}}}{W_{\text{process}} + W_{\text{time}}} \times \frac{S_{\text{process}}^\text{time}}{5} \cdot \frac{W_{\text{process}}}{W_{\text{process}} + W_{\text{time}}} \]

Weighting\( W_{\text{exp}} \), \( W_{\text{time}} \) should be defined by user.
Residential Houses Construction Processes Model

Software Demo

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