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# Rehabilitation Model for School Buildings

Shehab, Tariq
Adham Noureddine
Elhami Nasr
Reza Haghighat
California State University, Long Beach
Department of Civil Engineering and Construction Engineering Management

Tariq Shehab
Adham
Noureddine Elhami
Nasr Reza
Haghighat

Department of Civil Engineering and Construction Engineering
Management California State University, Long Beach

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Synopsis:

This paper presents a prioritization system for the rehabilitation of Kindergarten through 12th grade public school buildings in California. This system builds on the current school condition assessment process and assists to allocate rehabilitations funds in a rational manner that assures addressing and prioritizing the most deteriorated schools.

# Rehabilitation Model for School Buildings

Tariq Shehab, Ph.D., Adham Noureddine, M.Sc., Elhami Nasr,Ph.D. and Reza Haghighat
Department of Civil Engineering and Construction Engineering Management
California State University, Long Beach

The condition of public school buildings in the US has severely deteriorated. It is estimated that about $300 billion may be required for their repair. To manage these repair projects, an expenditure prioritization system is required. The current prioritization practice lacks a structured methodology that rationalizes its outcomes, which may also lead to misleading conclusions, and accordingly, misuse of available resources. This paper presents a prioritization system for the rehabilitation of Kindergarten through 12$^{th}$ grade public school buildings in California. This system builds on the current school condition assessment process and assists to allocate rehabilitations funds in a rational manner that assures addressing and prioritizing the most deteriorated schools.

**Key words:** prioritization, school buildings, analytical hierarchy process, decision making

## Introduction

The condition of the Kindergarten through 12$^{th}$ grade public school buildings has deteriorated over the past few decades. It was documented that their conditions may be considered unsafe to students and/or may interfere with classroom instruction (ASCE, 2009; Frazier, 1993 and Noureddine, 2010). To repair these schools, about $300 billion may be required.

To properly manage these repair funds, the overall condition of each school building needs to be assessed. To do so, most school districts use the School Facility Condition Evaluation procedure developed by California's Coalition for Adequate School Housing (Noureddine, 2010 and Rozzi, 2008). This procedure evaluates fifteen major building components, which are as follows: gas pipes; heat, ventilation and air conditioning (HVAC) and mechanical systems; windows, doors, gates and fences; interior surfaces such as walls, ceilings and floors; existence of hazardous materials; structural elements; fire safety precautions; electrical systems; pest and vermin infestation; drinking fountains; sewer systems; roofs; external toys such as slides on playgrounds; overall cleanliness of school and restroom fixtures.

Currently, the condition of each building component is determined using a scale that ranges from 0 to 100. The mathematical average of all components is calculated, and considered as the overall rating of each school. When rehabilitation projects are selected, districts give preference and more priority to schools with less overall rating conditions. This current practice does not consider the importance of each inspected component, therefore may lead to inaccurate results.

To overcome the limitations of the current prioritization practices of California school rehabilitation projects (i.e. lack of weights that reflect on the importance of each decision attribute and/or subjective judgment that may lead to irrational conclusions), the use of the Analytical Hierarchy Process (AHP) is proposed. This paper summarizes earlier research work published by the authors that proposed a prioritization tool for school rehabilitation projects and suggests future research work (Shehab and Noureddine, 2013).

AHP is a powerful tool that prioritizes many rehabilitation projects such as bridges, pipes and roads (Dalal et al., 2010; Khademi and Sheikholeslami, 2010; Al-Barqawi and Zayed, 2008; Shapira and Simcha, 2009; Farhan and Fwa, 2009; Vaiday and Kumar, 2006). The proposed system provides a tool that points to the neediest schools for repair jobs in a rational manner. To demonstrate the use and capabilities of the proposed system, a case study is presented.

## System Development

The AHP is a mathematical tool that ranks qualitative and quantitative attributes against each other (Abodayyeh et al., 2007, Saaty, 1982). Implementation of the AHP process includes three steps: 1) structuring hierarchies; 2) establishing priorities; and 3) calculating weights. Detailed descriptions of these steps can be found in Shehab and Noureddin, 2013.

### *Building the Hierarchy*

To build the hierarchy of the proposed prioritization system, all decision attributes need to be organized to reflect their mutual relationships. To do so, the outputs of the California School Facility Condition Evaluation report need to be used. Furthermore, either the UniFormat or the MasterFormat classification system needs to be considered. In this paper, the UniFormat system was privileged due to its better performance in rehabilitation projects (Johnson, 2007).

Through the close review of the CSI UniFormat Classification system and the building components addressed in the Facility Conditions Evaluation report, a four-level structure was built (Figure 1). The proposed structure was reviewed and supported by industry professionals through personal interviews.

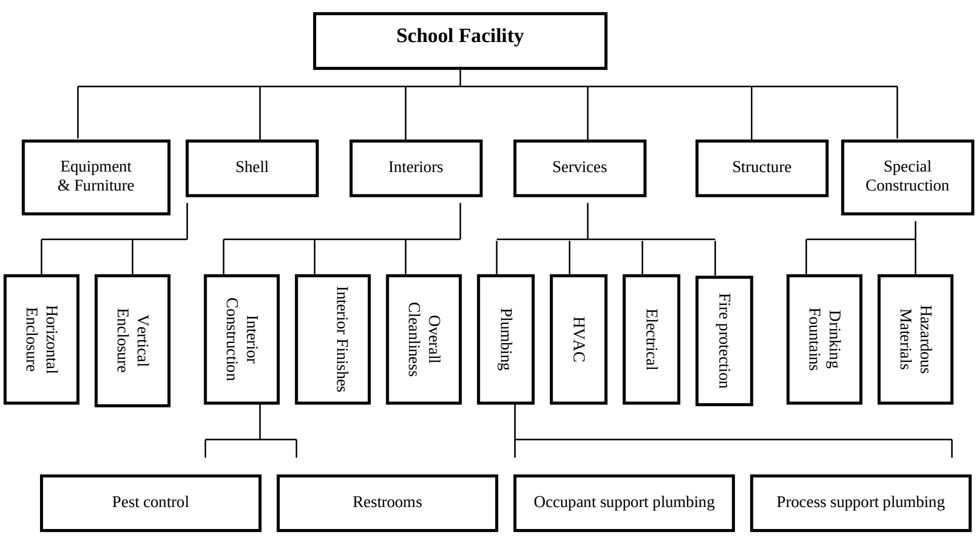


Figure 1: Hierarchy Structure

*Setting Weights of Components*

To set the weights of attributes for the proposed prioritization model, a questionnaire was designed and sent to 70 industry experts. It solicited the relative importance of all items addressed in the Facility Condition Evaluation report. The 43 returned questionnaires revealed that they were completed by construction experts who have 5 to 30 years of experience (Noureddin, 2010). It should be noted that this response rate (i.e. 61%) was considered to be satisfactory (PeoplePulse, 2012 and Hager et al., 2003).

Relative importance information was processed according to the AHP procedure to calculate the weights of all criteria at each hierarchal level shown in Figure 1. A detailed description of this process is presented in Shehab and Noureddin 2013. Figure 2 depicts the weights of all attributes. It should be noted that these weights have been calculated using consistent importance intensity revealed by the industry experts. Their consistency was demonstrated through a consistency ratio less than or equal to 10%. Noureddin 2010 describes a detailed process to calculate consistency ratios.

As shown in Figure 2, the three highest weights are associated with structural components (46%), vertical enclosures (11%) and horizontal enclosures (9%). The weights of all other building components range from 1% to 5%.

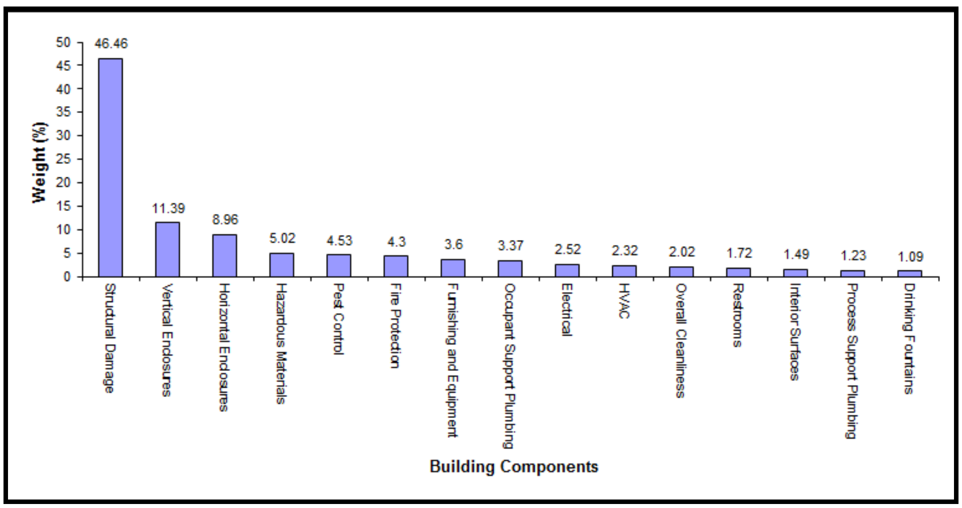


Figure 2: Building Component Weights

*Computer-Assisted Prioritization Tool*

To facilitate the prioritization process of school rehabilitation projects, a computer system was developed (Figure 3), which shares the knowledge and experience of industry experts with decision makers and other end users. As shown in Figure 3, the developed system prompts a user to select the School Facility Condition Evaluation reports associated with a school. This is achieved by clicking on “Read from Excel.” Once the report is retrieved, its information (i.e. the severity of the reported defects) is extracted by clicking on “Determine School Condition.” The process is repeated by using the “Enter New School” button until the information reported on all School Facility Condition Reports is extracted. The conditions of all school buildings are further processed using the principles of the AHP process (Abodayyeh et al., 2007, Saaty, 1982) and the weights depicted in Figure 2 to rank the priority of school rehabilitation projects.

To demonstrate the use and capabilities of the developed system, information pertaining to ten school buildings was extracted from School Facility Inspection reports. The current rehabilitation project prioritization system was followed by calculating the mathematical average of all building component conditions for all included schools. These conditions ranged from 85.7 to 98.7 (Table 1). According to these calculated building conditions, the rehabilitation priority of the ten schools is shown in Figure 4. Upon implementing the developed system, weights of building components and the AHP process, the priority list was changed (Table 1).

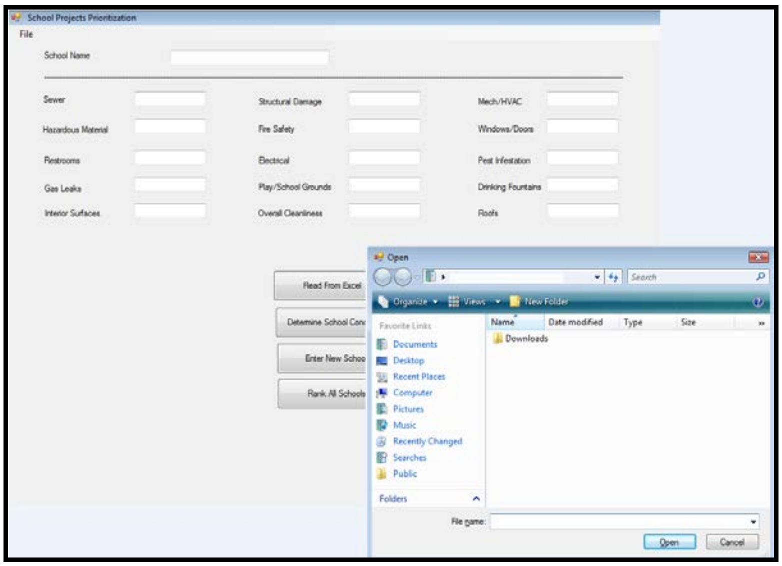


Figure 3: Developed System

Table 1
Comparison between the current and proposed prioritization systems

| School No. | Average building condition as reported on School Facility Inspection reports | Schools ranked according to the current industry practice | Schools ranked according to the developed system |
|---|---|---|---|
| 1 | 96.8 | 12 | 3 |
| 2 | 95.3 | 3 | 12 |
| 3 | 88.1 | 5 | 5 |
| 4 | 98.1 | 9 | 10 |
| 5 | 89.8 | 10 | 9 |
| 6 | 98.7 | 7 | 8 |

| School No. | Average building condition as reported on School Facility Inspection reports | Schools ranked according to the current industry practice | Schools ranked according to the developed system |
|---|---|---|---|
| 7 | 92.4 | 8 | 7 |
| 8 | 92.7 | 2 | 2 |
| 9 | 90.5 | 11 | 11 |
| 10 | 90.7 | 1 | 1 |
| 11 | 95.5 | 4 | 4 |
| 12 | 85.7 | 6 | 6 |

## Future Research Work

Despite the presented advantages of the developed prioritization system, its application is limited only to school buildings on a macro level (i.e. it considers each school as one entity and ranks its need for repair jobs among a pool of many others). To improve its performance, further research work will be performed to upgrade the proposed prioritization methodology to a more detailed level. In so doing, the system will compare all schools' building components and indicate the buildings that are associated with the most repair needs for specific components. For higher system's flexibility, these specific components will be specified manually and/or automatically.

The detailed prioritization system will allow school districts to allocate budgets for repair of specific building components in a manner that maximizes buildings' efficiencies, structural integrities and/or safety. The system will maximize its objective(s) within certain limitations, such as availability of funds and/or time. To develop this detailed prioritization system, an optimization tool will be used.

A number of optimization tools have been presented in the literature, among which is the Genetic Algorithm (GA). GA is associated with many advantages, such as its ability to perform in multi-objectives environments (Orabi and El-Rayes, 2012). It has been used in many infrastructure rehabilitation projects, such as highways and airports (Orabi and El-Rayes, 2012 and Khalafallah and El-Rayes 2006).

## Conclusion

A computerized prioritization system for kindergarten through 12th grade public school buildings in California was developed. The developed system overcomes the limitations of the current prioritization practice, such as lack of consideration of building component weights and/or potential for subjective conclusions. It provides a user-friendly tool that uses industry experience in prioritization processes. The use of the developed system is limited only to California school buildings that are inspected in accordance to School Facility Condition Evaluation procedures. A case example was presented to demonstrate the capability of the developed system and to compare its outcomes with the current prioritization practice.

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