Developing a decision support system for effective material management in construction

Abstract

An effective material management can improve productivity, reduce cost, and help the timely completion of a construction project, and thus, plays a key role in the project's success. However, the material management process in construction suffers from several issues and the process is not so effective. To improve the material management effectiveness, this study aims to develop a decision support system that can address the critical issues. However, the questions raise: which issues are critical and should be addressed in the decision support system; and how to develop such a system. Identification of the critical issues enables to define the specific aspects that need to be emphasized in the material management decision support system.

To answer the research questions, it is required to identify the real facts and figures to understand the current state of practice in material management as well as to develop and test hypotheses for determining the critical issues. Thus, pragmatism research philosophy, which suggests the use of both the positivism and interpretivism philosophies, is found suitable in this study. Moreover, both the quantitative and qualitative data are required to address these questions, which shows the requirement of a combination of deductive and inductive approaches. Besides, primary data in the form of interviews and surveys, and secondary data in the form of the literature review are the need of this study to answer the questions.

To address the research questions, this study focuses to identify the critical issues pertaining to the Indian construction industry. An extensive literature review identifies that limited studies are conducted focusing on the existing practices and critical issues in material management in the context of the Indian construction industry. Therefore, this study explores the material management state-of-practice in India based on interviews with material

management experts as well as two questionnaire surveys—Part I and Part II. The descriptive statistical analysis of Part I and Part II survey data identifies that level of implementation of traditional and sustainable material management practices is unsatisfactory and needs improvement. Moreover, analysis of Part I survey data, using exploratory factor analysis and structural equation modelling, determines that improper delivery of materials is the most critical issue disrupting projects' schedule and cost performances, followed by inadequate planning of materials, lack of information and communication, financial issues in procurement, changes in scope of materials, and difficulty in transportation. Thus, this study focuses to address the two most critical issues—improper delivery and inadequate planning of materials—in the development of the decision support system to improve material management. By examining the influence of material management issues on the disruption of projects' schedule and cost performances and determining the critical issues, this study contributes to the relevant body of knowledge relating to material management in the construction industry.

Identification of these two most critical issues reveals the further need to emphasize the assessment of lead time, prioritization of procurement of materials based on their criticality values, and development of an optimum material procurement schedule, which are the key aspects of material management relating to material planning and delivery. It also determines that these key aspects should be incorporated into the decision support system.

An appropriate material management system requires estimation of, and classification based on, the lead time of construction materials. To estimate the lead time precisely, the identification of the factors that influence it is essential. Previous studies in material management have not comprehensively examined the factors that influence lead time and have not emphasized the classification of materials based on the lead time. To address this, the present study has collected a large sample of procurement data from 16 building construction projects in India. A two-step cluster analysis has resulted in three clusters, namely long lead

(L), moderate lead (M), and short lead (S), referred to here as LMS based on the average lead time of the materials. Combining the LMS classification with the existing ABC classifications, where materials are classified in A, B, and C types based on their usage values can facilitate more reliable control over the inventory of materials. Furthermore, the regression analysis of the procurement data determines that the lead time of construction materials is positively correlated with the unit price and order value but negatively correlated with the project value. Besides, the capacity of a supplier has a negative influence on the lead time of bulk materials. The findings of this study would enable construction practitioners to precisely estimate the lead time of materials, thereby enhancing the availability of materials for the project.

Prioritization of procurement of materials based on their criticality values is an important aspect of material management relating to material planning and delivery. In this context, total criticality (TC) values of materials are determined by combining their material criticality (MC) and activity criticality (AC) values. Based on the data collected from Part III and Part IV surveys and using an integrated analytic network process (ANP) and technique for order preference by similarity to an ideal solution (TOPSIS) method, the MC values of materials are determined. The AC values are determined using float available in associated activities. Among the nine building materials considered in this study, the TC value of structural steel is found to be the highest followed by reinforcement bar, cement, autoclave aerated concrete block, coarse aggregate, tiles, sand, plywood, and biding wire. The results are validated further based on Part V questionnaire survey and using the Spearman's rank correlation (R) test. Therefore, this study provides a novel approach for assessing the criticality values of construction materials which adds value to the existing body of knowledge. Moreover, the TC values would help practitioners to prioritize the materials for procurement. The criticality values of materials are further used as a measure of shortage impact in the optimum material procurement schedule, as discussed below.

The development of an optimum material procurement schedule is another critical aspect relating to material planning and delivery. The procurement schedule would help in procuring the correct materials at the right time and for the lowest cost in construction projects. However, few studies examine the development of a material procurement schedule by integrating construction schedule and optimizing material costs as well as any material shortage impact. In addition, budget constraints and maximum storage capacity are rarely captured in the existing models for material procurement optimization. The present study has addressed these shortcomings and developed an optimization model incorporating all these aspects and using the nondominated sorting genetic algorithm II (NSGA II), which is executed in MATLAB R2017a. Implementation of this model in a building project results in a significant saving in procurement costs and shortage impact of materials.

Finally, this study develops a material management decision support system (DSS) integrated with lead time, criticality values of materials, and optimum material procurement schedule. For this, a framework for the DSS is developed first. Next, a user interface is developed for the DSS using visual basic for application (VBA) and MATLAB program. Following this, the effectiveness of the DSS is measured based on responses collected from Part VI and Part VII surveys. An ANP method and a scoring model method were deployed for the analysis of data. Furthermore, a t-test is performed that determines significantly improved effectiveness of the DSS compared to the existing material management systems used by the construction organizations. Therefore, the developed DSS can be used in construction to improve the material management effectiveness, particularly the material planning and delivery. Since very few previous studies have emphasized these critical aspects and developed a decision support system incorporating them to improve the material planning and delivery in construction, this study significantly contributes to the existing body of knowledge.