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Supplier selection process in an integrated construction materials management model

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ABSTRACT

The procurement and management of construction materials involve challenges related to reducing inventory, speeding delivery, and increasing the control of materials, thus decreasing the overall project cost. The objective of this research was to define and develop an integrated construction materials management (ICMM) model to address these challenges by deploying principles of virtual inventory management, feasible materials management networks, and a supplier selection process. Contributions include the development of the ICMM model and the demonstrated potential of the selection supplier process for improving procurement for construction projects. The use of the supplier selection process has been demonstrated through implementation on an industrial project and using the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method. This process optimizes and validates purchasing at each stage of fabrication for each construction package. A variety of project-specific criteria are involved in the supplier selection process, including price, lead-time, cash rebate, and supplier performance.

1. Introduction

Construction materials management can best be defined as "the planning and controlling of all activities necessary for ensuring and confirming that the correct and accurate quantity and quality of materials and equipment are appropriately specified in a timely manner, are obtained at a reasonable cost, and are available when needed" [1]. In typical construction projects, the cost of materials can constitute 50% to 60% of the total cost of the project [2–5], and their management affects 80% of the project schedule [6]. Strong evidence shows that an effective and optimized materials management system can ensure the availability of sufficient quantities of materials and equipment for construction needs and the minimization of surpluses at the end of the project [7,8]. Because of their role as important and complex functions of a project, construction materials management systems and their elements require substantial improvement [4], creating significant demand for both their enhancement or amendment and the development of new applications.

The CII *Materials Management Handbook* lists critical elements that can cause shortages of materials: lost or damaged materials, materials required but not purchased, materials purchased but not received, errors in material takeoff, variances in additional material requirements, and materials that are issued to crafts and are not used or installed [8]. These elements of materials management systems are associated primarily with the purchasing process. Purchasing usually involves tasks such as selecting and awarding suppliers, analyzing proposals, delivering purchases, inspecting goods supplied, and maintaining a variety of purchasing records [9]. This paper introduces a supplier selection procedure for facilitating the purchasing process. The TOPSIS method has been used to demonstrate the new procedure for an industrial project.

Two factors associated with construction materials management should be noted. The first is that the specification of an integrated construction materials management system should be conducted over a reasonable period and as a strategic decision during the Front End Planning (FEP) phase [9]. The second is related to the fact that materials management is affected by the "temporary multi-organization" [10] nature of uniquely defined and executed projects [11,12] that are characteristic of the construction industry. As with other construction systems, any supplier selection process developed should therefore be flexible enough to meet the materials management requirements for a wide variety of projects. The process presented in this paper was created with this goal in mind.

Section 2 provides a review and summary of the scholarly works whose concepts informed the research presented in this paper. The section is arranged thematically so that it corresponds to the steps involved in the developed supplier selection process. The discussion covers a synthesis of current knowledge as well as the gaps between existing construction materials management practices and the desired model, which were subsequently addressed through the development

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of an integrated construction materials management model (ICMM) for the industrial construction sector. While some articles and studies were drawn on more heavily than others, and some provided a direction for reflection rather than actual concepts, all of the work cited provided insights that proved valuable in the development of the model. Section 3 presents the vision of this research with respect to the development of the ICMM based on the needs and knowledge gaps identified through the literature review. Individual elements of the developed ICMM are also described. In Section 4, the approach taken during the creation of the supplier selection process is explained, and Section 5 discusses the implementation of the new process in an organization for a specific project, based on a real case study. Section 6 presents the conclusions that can be drawn from our findings.

2. Important concepts and characteristics of materials management

Construction materials management is a multi-disciplinary field that is appropriate for and can build on the correspondence between construction processes and some aspects of the manufacturing industry that entail a variety of activities for the large-scale conversion of raw materials into finished products (fabricated products). Thus, some manufacturing principles may be appropriately applied to construction as staged-fabrication.

Because EPC (Engineering, Procurement and Construction) entities and construction companies often cannot perform all required project tasks on-site in an efficient and timely manner, construction managers (experts) have tended to use staged-fabrication technologies whereby operations traditionally performed on-site have been moved to a manufacturing environment. Staged fabrication offers an opportunity to overcome some of the challenges associated with construction materials management, such as the absence of site inventories, demanding schedules, permit requirements, and adverse site conditions [13,14]. The staged-fabrication method is addressed in the next section, followed by a discussion of site materials management and other relevant concepts.

2.1. Materials management for staged fabrication (off-site)

Staged fabrication is a method of working with contractors so that value is added at the appropriate "stage" in the supply chain, and the resulting products such as pipe spools and precast concrete elements are efficiently delivered to a construction site. The value of such techniques includes the possibility of enhanced quality control, improved design details, compressed schedules, and reduced reliance on site labor. These benefits come at an increased cost for some projects, but the additional cost could decrease over time, as the construction industry becomes familiar with the staged-fabrication process [15]. Already, the application of staged-fabrication principles to construction materials management is beginning to demonstrate benefits with respect to quality, time, and cost savings [16–18]. Materials management for staged fabrication is concerned with both the input and output of the fabrication process.

Implementation of staged-fabrication requires the collaboration of clients, developers, designers, contractors, manufacturers, suppliers, government agencies, advisors, and researchers. A variety of staged-fabrication strategies are commonly used in the construction industry, including semi-prefabrication, prefabrication, comprehensive, and modular [19]. With respect to transportation considerations, prefabricated elements have a higher added value than bulk materials. The materials to be delivered are, in fact, manufactured products with value added by a separate workforce, and the percentage of the total costs represented by the amount required for direct labor and materials for a project may thus change if additional fabricated products are incorporated into the construction project [20].

2.2. Site materials management

In recent years, there has been an increased research interest in the materials management theories and methods. These researches recommended an integrated management of the interface between site activities, the computer systems that are used for design and scheduling, and other components of the integrated materials management model [21–23]. The potential benefits to the integrated materials management include: high accuracy, low cost, and robustness [24]. The attributes of materials management systems that contribute to the success of a project were identified by some scholars and experts [8,25,26]. They associated their findings related to the attributes of materials management systems for mega and complex industrial construction projects with the control of the functions related to quantity takeoff, vendor evaluation, purchasing, expediting, receiving, warehousing, and distribution. These findings showed that lack of proper management of these functions leads to shortages and surpluses of materials and to cash flow problems.

Bell and Stukhart (1995) quantified the savings in the areas of improved labor productivity, reduced surpluses of bulk materials, fewer manpower requirements for materials management, and enhanced cash flow. Surpluses of bulk materials were reduced from a range of 5% to 10% of the amount purchased to about 1% to 3% of the amount purchased. This study also showed that an efficient materials management system can reduce the man-hours needed for materials management; in the absence of a materials management system, craft foremen spent up to 20% of their time searching for materials and another 10% tracking purchase orders (POs) and expediting delivery [25].

2.3. Planning and control for materials management

One of the most important elements of any effective construction materials management system is planning [3]. Materials planning integrates and combines the functions of vendor enquiry and evaluation, project planning, purchasing, material takeoff, transportation, field materials control, and warehousing [3]. Significant cost overruns can be caused by shortages of materials resulting from lack of proper materials planning and control. Improper materials planning and control result in: the absence of adequate statistics related to the availability of the materials, a shortage of funds for procurement (budgeting), inadequate transportation capacities, excessively long average waiting times and uncertainty about the delivery of the materials ordered and about the availability of some materials [8].

Transparency among the suppliers, subcontractors and owners is important for materials planning [27]. The subcontracting concept is crucial in the materials management process, which should be considered over developing and implementing the ICMM. The scope of the subcontracts and lists of equipment and materials to be furnished by subcontractors are defined during the planning stage [28,29]. The critical materials are usually procured by the owner (or an EPC), while the minor equipment and bulk materials may be furnished by the subcontractors. In general, subcontracting requires considerable effort on the tasks of materials procurement and scheduling but relatively less emphasis on tasks related to the on-site materials management [30,31].

Transportation planning, materials specification and a coding system are important functions of construction materials planning. Transportation planning should include consideration of cost, safety, timely delivery, and hazardous materials content. A materials specification and coding system must first be established for handling bulk materials. A materials takeoff establishes the quantity of bulk and engineered items needed for the project, based on the design. However, the creation of composite items requires that they be quantified and arranged based on their relationships, therefore a Bill of Materials (BOM) must be created from the materials takeoff in order to define the requirements with respect to project materials.