Performance evaluation of material handling system for a warehouse

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This paper attempts to find out the best available alternative material handling system (MHS), an integral component of warehouse operations. Analytic Hierarchy Process (AHP), a flexible decision making tool for complex, multi-criteria problems and useful to provide management weightage, has been used in this study to develop performance model. The proposed algorithm, used to select the proper MHS is the hybrid of AHP performance model and capital investment. Sensitivity analysis has also been reported for making an eclectic decision. The newly developed method is sound surrogate to the traditional techniques.

Keywords: Analytic Hierarchy Process (AHP), Material-handling system (MHS), Performance model, Sensitivity analysis

Introduction

Fierce global competition and increased cost awareness among customers have a direct effect on the design of material-handling system (MHS), an integral component of warehouse operations. Material handling may cost 20-50% of the total operating cost in manufacturing operations¹. Some of the important studies on MHSs are construction algorithm², which formulated the problem as an integer-programming model to minimize operational and investment cost of the selected equipment. MHS selection methodology, linking product design with manufacturing logistics design, was developed³ for manufacturing environment only. A mathematical model was developed to select MHS proposing a 0-1 integer-programming model to maximize the adaptability factor, emphasizing more on choice of technology¹. Concurrent engineering approach for MHS selection using ABC and Economic value analysis emphasizing much on cost factor to justify investment in automated material handling was studied⁵. Allocation model, which interfaces with MHS selection model by using data from machining centre, was developed without emphasizing on capital cost⁶. These models are complex and could not address the performance criteria well, and more focused on cost. None of these studies considers intangible factors such as working safety, user friendliness, product damage etc.

Analytic Hierarchy Process (AHP)⁷, developed to structure complex, multi attribute problems, can consider these criteria well. It is based on pair wise comparison of decision elements with respect to a common criterion. AHP provides a framework for prioritizing goals, objectives and alternatives. Important studies on AHP are on investment analysis evaluating tangibles and intangibles of capital investment⁸, investment analysis using activity based costing concepts and AHP by developing performance impact model and cost impact model⁹, performance evaluation of existing vendors of a factory to reduce the number of vendors¹⁰, professionals’ selection for organisations¹¹ and credit evaluation of manufacturing firms in turkey¹². The idea expounded and propounded in the paper on plant location problem¹³ is mostly extended in the present investigation. Relationship between goals, activities and performance measures are established by using AHP to prepare performance model (PM)⁹. For this purpose, an algorithm, Material Handling Equipment Measure (MHEM) is proposed, where results of AHP-based PM will interface with the capital investment. This algorithm is applied in a real life case, for a factory warehouse situated in Faridabad near Delhi. Sensitivity analysis was carried out to discuss the importance of coefficient of attitude (β) in the final outcome.

This paper presents usefulness of AHP to generate a PM, which interfaces with capital investment in the

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proposed algorithm to get the final result and provides a more consistent weighing scheme for the final selection of MHS. This concept is rational, logical, exotic and comprehensive; simple calculations are performed to judge and compare the performance of the alternatives.

Methodology

Results from PM interface with capital investment in the proposed algorithm. MHEM is calculated from proposed algorithm to determine final score for each alternative MHS. To verify effectiveness of final outcome of the present methodology, sensitivity analysis is performed.

AHP Performance Model

Objective of PM is to choose the best available alternative with respect to performance using AHP to improve functioning during usage of MHS. If an investments decision is taken without considering performance measures, intangible benefits cannot be quantified in the decision process. PM establishes relationship between investment alternatives, performance measures, activities and goals, where strategic goals are attributed, activities and performance measures are sub attributes. Priority weights are obtained using pairwise comparison of AHP (Fig. 1).

Performance measures such as lead-time, transit damage, man-hours per product and energy per hour are considered while developing PM. Under man-hours per product, both maintenance man-hours and materials transportation man-hours are considered. This provides an effect of running cost on investment alternatives. By traditional experience or from product related information supplied by the manufacturer, operating cost or resource usage for each type of investment alternative can be compared. These estimates are considered while assigning weightage to the alternatives into PM. After assigning all the priority weights, weights are multiplied along each path leading to an alternative and add those to arrive at the final score of PM.

Proposed Algorithm

Consider a warehouse where, i = 1, 2,………, n; number of material handling alternatives considered for proposed analysis. MHEM for ith alternative can be calculated as

$$MHEM_i = \beta \cdot (CFM_i) + (1-\beta) \cdot (OFM_i) \quad \ldots(1)$$

where $0 \leq \beta \leq 1$ and $\beta$ is known as coefficient of attitude. Also, $0 \leq CFM_i \leq 1$ and $CFM_i$ = Composite factor measures for ith alternative.

CFMs are score obtained from AHP performance model for each alternative.

$$\sum_{i=1}^{n} CFM_i = 1$$

Also, $0 \leq OFM_i \leq 1$, $OFM_i$ = Objective factor measure for ith alternative and calculated as

$$\sum_{i=1}^{n} OFM_i = 1$$

$$OFM_i = [AFC_i \times \sum_{i=1}^{n} 1 / AFC_i]^{-1} \quad \ldots(2)$$

$AFC_i$ = Alternative factor cost for ith alternative, i.e capital investment required for ith alternative.

To verify the result of proposed algorithm, sensitivity analysis is carried out by changing the value of $\beta$ in Eq (1).

Case Study

As a response to changing business scenario, management has decided to replace the old MHS to meet certain strategic goals. Strategic goals as capacity, user friendliness, productivity and safety are used to evaluate three different new MHS coded A, B and C. The study was conducted for an electrical goods manufacturing firm. To hide the identity, name of the organization and name of the alternates will not be discussed. In this paper, all the cost calculations are on Indian Currency (Rs).

AHP Performance Model

To evaluate the alternatives, performance measures are chosen in consultation with management. Activities identified for MHS selection are incoming transportation and storage, pick up and final delivery. Transportation of incoming materials involves pick up from a designated place and transportation to a designated storage place and storage. Transportation of final delivery includes pick up stored materials to be dispatched and transport to a designated place for delivery. Using pairwise comparison of AHP technique, priority weights for strategic goals, activities and performance measures are developed. Steps for calculation of relative importance under the MHS ‘A’ are,
First calculate up to incoming and store activity

\[0.15 \times 0.5 + 0.35 \times 0.4 + 0.25 \times 0.4 + 0.25 \times 0.5 = 0.44.\]

Up to pick and delivery activity

\[0.15 \times 0.5 + 0.35 \times 0.6 + 0.25 \times 0.6 + 0.25 \times 0.5 = 0.56\]

Then the relative importance for MHS ‘A’ can be calculated as

\[(0.44 \times 0.1 \times 0.4 + 0.44 \times 0.3 \times 0.4 + 0.44 \times 0.25 \times 0.3 + 0.44 \times 0.35 \times 0.3) + (0.56 \times 0.2 \times 0.4 + 0.56 \times 0.25 \times 0.4 + 0.56 \times 0.3 \times 0.3 + 0.56 \times 0.25 \times 0.3) = 0.343\]
Similarly, relative importance under MHS ‘B’ and ‘C’ are 0.335 and 0.322 respectively. As per this model preference order is A>B>C. MHS ‘A’ is slightly favoured as compared to others. Then the result of AHP-based PM will interface with the proposed algorithm for final ranking of alternatives. For investment alternatives, A, B and C, capital investment required are, Rs. 5900000, Rs. 3050000 and Rs. 3750000 respectively.

Expected life of the alternative MHS is not considered in present study. But present vibrant competitive business does not permit organizations to utilize the full life cycle of the equipments, but are compelled to scrap those quiet earlier to get competitive business advantage.

Choosing MHS Alternative

The value of $\beta$ (0.67) is obtained from the brainstorming session between experts from design, maintenance, and production. Results obtained from AHP model are: CFM$_A = 0.343$; CFM$_B = 0.335$; and CFM$_C = 0.322$. Capital investments required for the alternatives are: AFC$_A = 5900000$; AFC$_B = 3050000$; and AFC$_C = 3750000$. Putting AFC values in Eq (2), OFM can be calculated as

$$\text{OFM}_A = [5900000 \times (1/5900000 + 1/3050000 + 1/3750000)]^{1/3} = 0.2218$$

Similarly, OFM$_B = 0.4291$ and OFM$_C = 0.3490$.

Putting these values in Eq (1), MHEM for MHS ‘A’ can be calculated as

$$\text{MHEM}_A = 0.67(0.343) + (1-0.67) 0.2218 = 0.303$$

Similarly, MHEM$_B = 0.67(0.335) + (1-0.67) 0.4291 = 0.366$, and

$$\text{MHEM}_C = 0.67(0.322) + (1-0.67) 0.3490 = 0.331$$

As per this algorithm, order of preference is B>C>A; though in terms of performance, MHS ‘B’ is the second preferred option.

Sensitivity analysis (Fig. 2) is done by putting various values of $\beta$ in Eq (1). Preference order (Fig. 2) remains the same (B>C>A) for a large value of $\beta$ (0 - 0.85). If $\beta > 0.85$, then preference order is A>B>C, which is same as AHP-based PM. For $\beta = 0$, MHEM = OFM i.e. dominance of capital investment factor. For $\beta = 1$, MHEM = CFM i.e. dominance of composite factor measures. Thus, if $\beta$ is moved from 0 to 1, dominance also moves from capital investment to composite factor measures.

Conclusions

This paper followed a two-tier process for MHS selection for a warehouse, which is different from traditional investment analysis, and is generally based on payback period. Investment alternatives that perform well during operations may not always result highest financial returns. This algorithm ranks investment alternatives considering both performance and capital investment. For performance evaluation, AHP was used. MHS, selected by neglecting any of the performance measure or capital investment, may lead to incorrect decision. MHS ‘B’ has been observed most favourable among all alternatives. Proposed methodology can also be used for the selection of Robot, Flexible manufacturing system, Advance manufacturing technology, Computer Integrated manufacturing, Projects, Site selection etc. Effectiveness of this model is further supported by sensitivity analysis.

References


