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Quantity of material handling equipment—A queuing theory based approach

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Abstract

In this paper, we discuss the development of a two step analytical approach to determine the quantity of material handling equipment (MHE) required for effective handling of products among facilities. In the first step, a preliminary solution is obtained by considering the time required for loading and unloading of products, loaded travelling, empty travelling and breakdown of MHE. A detailed model, which integrates both operational and cost performance factors such as utilisation of MHE, work-in-process at the MHS and life-cycle cost, is then utilised to rank alternatives that are generated from the preliminary solution. The stochastic nature of a manufacturing system, which is not adequately addressed in the literature, is best modelled using queuing theory. An illustrative problem is given, and it is shown that for all the considered problems our approach outperforms the existing methods. The influence of various other factors including the operational characteristics of processing facilities, layout design, maintenance function, MHE speed and batch size in selection of the quantity of MHE is also demonstrated. Thus we show the significance of our proposed approach and its capability to support an integrated decision making process.

Keywords: Material handling system; Quantity of MHE; Work-in-process; Performance evaluation

1. Introduction

A material handling system (MHS) acts as an inter-connector for facilities and should facilitate the process of delivering the right amount of materials, to the right place, at the right time and at the lowest cost. An effective MHS improves the performance of a manufacturing system, mainly by reducing work-in-process (WIP). Material handling cost encompasses between 15% and 70% of the total operating cost [1]. Hence, it is in manufacturing enterprises' best interest to look for ways of improving the effectiveness of their MHS. Effectiveness of this system can be achieved by making appropriate decisions about its various constituent features which can be classified into two groups, and they are:

(1) Design features (related with design of a MHS).
  (a) Number of material handling equipment (MHE).
  (b) Material flow path that reduces total travelling time, which includes decisions related with:
    (i) Type of flow path (uni-directional/ bi-directional/ combination).
    (ii) Location of pick-up and delivery points.
  (c) Transportation batch size-number of parts in an unit of transportation load.
  (d) MHE dispatching policy.
(2) Operational features (related with operation of a MHS).
  (a) Operational schedule for MHE.
  (b) Maintenance schedule for MHE.

Selection of an appropriate combination of the above design and operational features has impacts on operational behaviours of a MHS including empty travel, variation in WIP, and variation in travelling time. These behaviours directly influence the performance of a manufacturing system. Considering such relationships between the MHS and manufacturing performance, we have developed an approach to analyse the effectiveness of a MHS [2]. The

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effectiveness analysis consists of three stages. First, the current effectiveness level of MHS is calculated. If the current level is not satisfactory, at the second stage identifies and prioritises the potential components of MHS that can bring improvements in its effectiveness. Third, the critical factors that cause the ineffectiveness of particular components are identified for further analysis (see Fig. 1). By utilising appropriate approaches, optimised recommendations are then deduced for the critical factors identified at stage three. However, the objective of this paper is to discuss about the proposed analytical approach that provide optimised recommendation for the 'quantity of MHE' factor required for meeting total material handling demand in a given time frame.

Literature is abundant with methods that are primarily based on minimising some functions of acquisition costs. However, total cost minimisation, which is a common and an important performance factor, is not necessarily the most appropriate or the only performance factor, as the actual operational performance is also becoming crucial in a decision making process [3]. Very few researchers have developed methods that optimise the quantity of MHE with respect to operational performance factors such as throughput time and utilisation. However, these performance based methods are developed from basic computational approaches, which are appropriate only to obtain preliminary solutions in the search of an optimal solution. Further, such performance factors are calculated without considering the inherent stochastic nature of the manufacturing system [4]. In general, arrival of products to MHS is a dependent of fluctuating product demand and processing rate of facilities. Similarly, the product handling rate of a MHE or simply the service rate is also stochastic due to natural variations in service time and divergence in travelling distance for transferring different kind of products. In addition, the MHEs are subject to unforeseen breakdowns. These intrinsic variations cause the queuing phenomenon and radically affect the operational performance measured by WIP and utilisation. On the other hand, competing attributes of a manufacturing enterprise including product cost, delivery time and quality are interconnected and are influenced by WIP values [5] (see Fig. 2).

To address these issues while incorporating the system's stochastic nature, we have developed a two step analytical approach to determine the required quantity of MHEs (Section 3). The first step finds preliminary solution by considering the total time available and the total time required for loading, unloading, loaded travel, empty travel and breakdown of the MHE. In the second step, a detailed model is demonstrated to rank alternative solutions for both operational and cost performance factors. A well established approach to quantify the variations in a manufacturing system, queuing theory, is utilised to evaluate the operational performance factors. In Section 4, we provide a numerical example and compare the results with two existing approaches. The results show that the proposed approach provides optimal and feasible solutions for all the considered problems which are characterised by different product flow data. Whereas, existing methods underestimate the quantity of MHE due to their inability

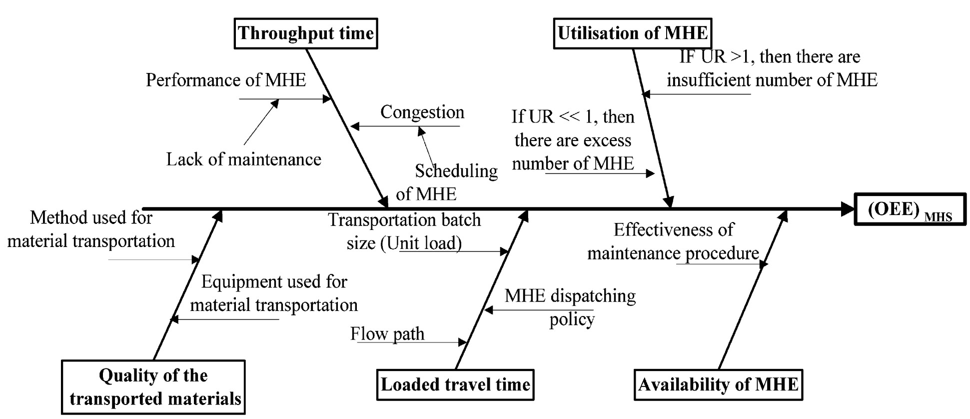

Fig. 1. Factors that determine the effectiveness of a MHS.

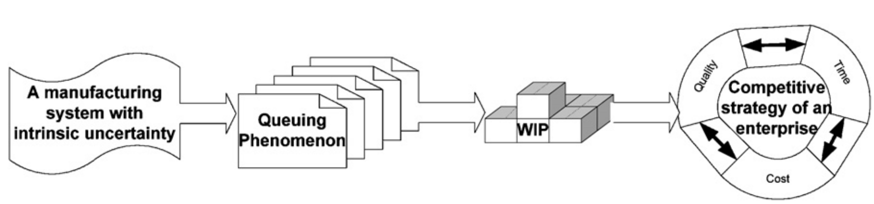

Fig. 2. Relationship between the uncertainty and performance factors.