AGV Based Material Handling System: A Literature Review

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***Abstract*- This paper is intended to provide a literature review of AGV based material handling system .Among the various factors influencing the design and operation performance of AGV in a manufacturing unit, literature review on four major factors are undertaken in this paper i.e. Throughput, Unit load, Flow path design and Fleet size. The study aims at revealing basic research methodologies/approaches followed, objective function and problem areas of the material handling system. The review study covers articles coming from major journals related with the topic. Findings reveal that AGV based material handling system is still an open area of research.**

***Keywords:* AGV, unit load, fleet size, throughput, flow path design.**

I. INTRODUCTION

Material Handling involves the movement of materials from one place to another for the purpose of processing or storing. According to American Material Handling society,' Material Handling is an art and science of involving the movement, packing and storing of subsystems in any form. Thus material handling function includes all types of movements vertical, horizontal or combination of both and of all types of material fluid, semi fluid and discrete items and of movements required for packing and storing. The material handling function is considered as one of the most important activities of the production function as out of total time spent by the materials inside the plant area, about 20% of the time is utilized for actual processing on them while remaining 80 % of the time is spent in moving from one place to another, waiting for processing or finding place in sub-stores. Moreover about 20 % of the total production cost is traceable as material handling cost. The relative percentage will vary according to the type of product, plant layout, production method, availability of resources like men, machine etc. In most manufacturing systems, the material handling system plays a critical role since it is primarily responsible for providing the right material at the right place, and at the right time. A poorly designed material handling system interferes with the efficient operation of a manufacturing concern and in the long-term it may lead to a substantial loss in productivity.

Automated guided vehicles are unmanned vehicles used to transport unit loads, large or small, from one locationon the factory floor to another. These vehicles are operated with or without wire guidance and are controlled by a computer. A system controller is responsible for the regulation of traffic when more than one vehicle is in the system. Automated guided vehicle systems (AGVS) are computer-controlled material-handling systems typically used for repetitive tasks in intermodal container terminals, distribution centers, storage and warehouses, manufacturing, and Assembly plants. An AGVS is composed of a fleet of automated guided vehicles (AGVs), a navigation network, and dispatching, routing, and traffic-management software. The vehicles are battery-powered, equipped with manual or automated pick-up and drop-off mechanisms as well as with automated obstacle-detection capability. Earlier navigation networks utilised wire or magnetic tape, but more recent technologies are optical, inertial, or laser. Unit loads AGVs represent the largest segment of the AGVS market. Automated material handling systems, though more flexible and capable than their counterpart (non-computer controlled systems), do pose more serious and challenging operational control problems. These control problems increase with the level of system automation. The manner by which these problems are resolved, determines the operating effectiveness of the total system, as typified by an Automatic Guided Vehicle (AGV) system .Among the new generation of material handling systems (MHSs), automated guided vehicles (AGVs) are the most widely used today in flexible manufacturing systems (FMS) and computer integrated manufacturing (CIM) environments.

AGVs are found to be flexible, modular and versatile. However, the failure of some of the installations, and the subsequent analysis of the reasons for failure, shows that careful design and operational planning of AGV-based material handling systems is required if the full potential of such a system is to be realized.

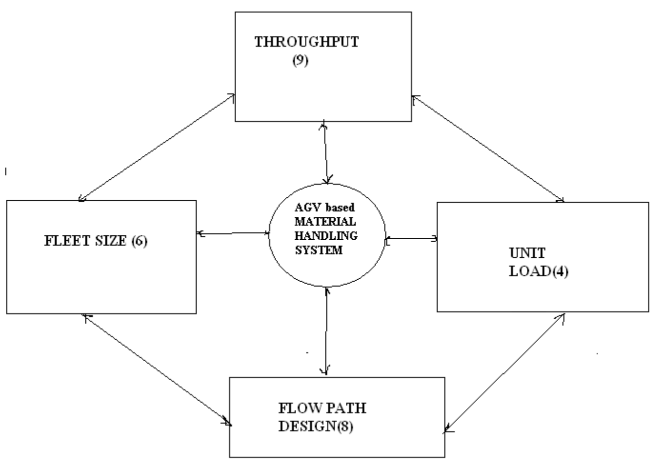
AGV can be regarded as intelligent transportation system in the manufacturing environment. In this paper a literature review on AGV based material handling system is carried out with respect to some of the various factors such as throughput, unit load, flow path fleet size , Unit load, , flow path design, throughput. This is the comprehensive review on some of the research of AGV based material handling to my knowledge. However no claim is made here that it includes all literature on AGVs. The scope of this survey has been mainly focused on results published in available research journals.

Review methodology is discussed in next section. Third section will discuss literature review on throughput, unit load, flow path design and fleet size. The final section gives conclusion.

II. REVIEW METHODOLOGY

27 papers are found much more relevant for the intersection of AGV based material handling and its various methodologies. Among the various factors influencing the design and operation performance of AGV four major factors are undertaken for study i.e. throughput, Unit load, Flow path design and Fleet size. As such, the review in this study is includes papers from following journals.

International Journal of Production Research	18 papers
Production planning and control	3 papers
IEEE transactions	6 papers
Total	27 papers



Factors influencing design and operation of AGV based material handling system

III. LITERATURE REVIEW

3.1 Literature on Throughput:

Job throughput is measured with respect to time and quantity. Job throughput time refers to the total time a job spends in the system (i.e. the time between the arrival of the job to the system and the departure of the same job from the system). This time incorporates processing, waiting, and travel (material handling) time. Throughput quantity, often simply referred to as throughput or production volume, is the number of jobs completed (or which exit the system) in a given period of time. Time required to complete a fixed number of jobs is a measure of throughput which is defined as the length of time required to complete fixed number of jobs..

Mandyam M. Srinivasan A , Yavuz A. Bozer B & Myeonsig Cho(1994) presented a general purpose analytical model to compute approximate throughput capacity of trip based material handling system used in manufacturing setting. The author claimed that model would be useful in early design phase and prior to simulation. Yang and Peters (1997) use a modified quadratic set covering problem formulation to solve the fab layout design problem. They propose a network flow formulation to determine the number and location of shortcuts for the inter bay transport system in a spine layout fabrication. Their objective function minimizes construction cost and the decrease in material handling costs. Meller (1997) proposes a mixed integer and dynamic programming approach to determine an optimal layout. Ting and Tanchoco (2001) propose two rectilinear layout configurations, single spine and double spine (where the two spines are perpendicular), and they present mathematical models to optimize both configurations. Agrawal and Heragu (2006) and Montoya-Torres (2006) discuss various approaches for automated materials handling in semiconductor manufacturing and review the literature on various aspects of factory design, such as facility layout, AMHS design and AMHS operational issues. Dima Nazzal a & Leon F. McGinnis(2008) did analysis of the throughput performance of a closed-loop multi-vehicle automated material handling system (AMHS) used in highly automated 300 mm wafer fabrication facilities (fabs). A numerical example is analyzed and simulated using AutoMod to demonstrate and validation of the stochastic model.

Research on throughput aspect is mainly useful at the design stage of facility layout. Most of the research is carried out in wafer fabrication industry. There is need to develop robust method which is useful for most of the industries.

3.2 Literature on Unit load:

Unit load size which may be defined as the number of distinct parts that can be aggregated and transported as a single unit by an AGV for processing in the shop. This quantity of parts to be handled at a time for each product type does significantly influence the operational efficiency of an AGV-based manufacturing system. P. J. Egbelu(1986) characterized AGV dispatching rules and also focused on selecting best unit load size in a flexible manufacturing system (FMS) using a procedure that is based on the application of mathematical programming, computer simulation, and statistics to minimize the total cost of manufacturing. B. Mahadevan & T. T. Narendran (1992) in their paper presented an integer programming formulation of the problem of finding the optimal unit load size. Using an analytical model to decide the number of AGVs required, an algorithm based on branching and implicit enumeration and a heuristic have been developed.

Also heuristic procedure has been developed for solving large-size problems.
Unit load size is a major area of research as it significantly affects the productivity. The research work on unit load is to obtain best unit load size using tools of mathematical programming, heuristics and simulation. There is further need to use modern operation research or integration of methods that will help to be useful for major FMS types of industries to determine unit load.

3.3 Literature on Flow Path Design:

The flow path design is one of the important factors in the overall design and operation of an efficient AGV system. The guide path layout will determine the overall distance traveled by the vehicles. An important factor in the design of automated guided vehicle systems (AGVS) is flow path design. Gaskins and Tanchoco (1987) gave the first model for the AGV Flow Path Design Problem.. The objective is to find the flow path which will minimize total travel of loaded vehicles. In their zero-one integer programming model, they assumed that the facility layout is given and the pickup/delivery stations are fixed. The mathematical programming approach fails to take into account the travel of unloaded vehicles, vehicle blocking, and congestion. Robert J. Gaskins A , J. M. A. Tanchoco A & Fataneh Taghaboni (1989) presented a model for determining the optimal flow path design for an AGVS with virtual flow paths. This model is a linear integer program and can be used with loaded vehicle travel data as well as empty vehicle travel data. But fails to take into account the interaction of the vehicles in the system. Such as vehicle blocking and traffic congestion. William G. Goetz Jr. A & Pius J. Egbelu (1990), addressed the problem of selecting the guide path as well as the location of pick-up and drop-off points for outward and inward bound parts to departments. They modeled the problem and solved as a linear integer program with the objective of minimizing the total distance traveled. Moshe Kaspi A & J. M. A. Tanchoco (1990) formulated an alternative model of the AGV flow path layout(FPL) problem which was first formulated by Gaskins and Tanchoco, as a zero-one integer programming problem the procedure is proposed is based on the branch-and-bound technique. An algorithm for satisfying the reachability condition for nodes in the AGV flow path network is also presented. But this model did not include the entire solution and have computational inefficiency; another was given by Kaspi and Tanchoco (1990). In this expanded model, several other constraints were added and the reachability problem was explicitly addressed. In addition, an efficient branch-and-bound procedure was described. In this paper, an improved algorithm is proposed wherein only the intersection nodes of the network are included in the branch-and-bound algorithm. The model used in this work is based on the formulation given by Kaspi and Tanchoco (2010). The objective of the model is to set directions to the arcs in an undirected graph which represents the flow path network so that the total vehicle travel distance is minimized. We will assume that the from/to flow matrix includes both loaded and empty vehicle travel in full-size.
The research on flow path design is carried with the objective to reduce the total travel distance. Initial research focuses on travel of loaded vehicle only but later extended to empty vehicle also.

3.4 Literature on Fleet size:

Fleet size refers to the number of AGVs needed to transfer the goods in the manufacturing set up. Egbelu (1987) presented four analytical procedures for estimation of vehicle requirements. These include two simple, rough cut, hand calculation methods, typically useful at the early stages of evaluation, a procedure applicable to situations in which there is no conservation of flow and specifically useful for job shops. Tanchoco (1987) proposed a method which is based on the CAN-Q model in which parameter C, known as the cycle ratio was used for computing the required number of AGVs. The vehicle requirement was higher for lower cycle ratios. Wysk (1987) used AUTO-Q, a spread-sheet pre-processor, in conjunction with CAN-Q for vehicle estimation. The vehicle requirement for each subsystem was computed independently but These models fail to accommodate routing flexibility of FMSs. Sinriech A & J. M. A. Tanchoco(1992) developed a model to determine of the number of vehicles needed to operate the system in an efficient and economical way. A multi-criteria optimization model is developed using two goals, cost and throughput performance and by using a trade-off ratio between the goals the number of AGVs needed in the systems is determined. Mahadevan A & T. T. Narendran (1993) developed analytical model for estimating number of AGVs required for FMS. Robert Arifin & Pius J. Egbelu (2000) determined number of AGVs in FMS environment using analytical and simulation modeling. The analytical method involves consideration of load handling time, empty travel time, and waiting and blocking time. Formulation of a mixed integer programme with an objective of minimizing empty trips. Simulation methodology is used to validate the initial estimates of fleet size. F. Fred Choobineh , Ardavan Asef-Vaziri & Xiaolei Huang(2012) used multi-class closed queuing networks to model operations of automated guided vehicles in a manufacturing as well as distribution environment. The steady-state behaviour of the closed queuing network by a linear program was modeled whose optimal value gives the fleet size. The result of the analytical model is compared with those of the simulation.

The research on fleet size is from general calculation of number of AGVs to accurate estimation by using range of mathematical models. Initial research considered one factor i.e. travel time for estimation of number of AGVs. Later the analytical models take into consideration loaded time, travel time, waiting time and blocking time which leads to refinement towards appropriate estimation. Simulation also plays significant role in fleet size determination. Further research work has to be directed towards reliability of the results obtained from mathematical model and simulation method.

IV. CONCLUSIONS

This study has put forward the various factors considered for the design and analysis of AGV based material handling system. The study revealed that there is need of further research on AGV based material handling. The following are the main guidelines identified for future research:

Developing measurement and performance systems in the form of new mathematical models and with changing approaches. There is need for cross industry study to make the method suitable for all type of industries. Most of the study is carried out with single factor such as fleet size, unit load, throughput, fleet size with respect to material handling. There is need to study the interdependency of factors and its effects with regard to each other.

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