Network Configuration for AGV Systems
with the Consideration of
Layout Changes and Fleet Size
(レイアウト変更と AGV 台数を考慮した
AGV システムのネットワーク形成に関する研究)

申請者
ウィラパット セスプーン
Weerapat Sessomboon

機械工学専攻
プラントエンジニアリング研究

1998 年 12 月
Competitive advantage of manufacturing firms can be achieved with a well-planned and implemented facility. A significant fraction of manufacturing cost for most products is due to material handling required for routing raw material, works in process, and other associated materials between different processing stations. The handling cost is traditionally considered as proportional to both of flow volume and distance between processing stations. The flow volume is determined by the level of production of each product and product mixes, which is the relative proportion of finished product. The production levels are driven by market demands, and typically are beyond the control of a planner. However, the distance between stations can be controlled, with some extend, through an efficient layout planning. Thus, it is that the stations to be laid out in order to minimize the material handling cost.

Numerous manufacturing companies have recognized the advantages of Automated Guided Vehicle System (AGVs) for material handling. These advantages include transporting flexibility, space utilization improvement and lead time reducing. With its state of art technology is rapidly advancing, it makes AGVs suitable for using in automated manufacturing systems. One of the design's difficulties of AGVs is its flowpath-network configuration. Unlike traditional layout planning, configuring AGVs' flowpath network involves not only locating machines but also determining transporting flowpaths and their directions. Moreover, a suitable number of AGV in the system, which is also known as fleet size, needs to be considered when designing AGVs.

Previous studies on AGVs have focused on optimizing flowpath-network configuration for a given layout. A solution from the layout-fixed condition might not be the best one since the best layout was not initially obtained. Moreover, number of transporter was not considered in these studies. Material handling between stations was assumed bulk transportation, and transportation was assumed readily at anytime. This means that AGVs' characteristics such as AGV empty travelling and congestion were not taken into the consideration. Despite a report on significant effect of these characteristics on the network configuration, they have long been excluded from the consideration due to their dynamic conditions. Therefore, it is the objective of this study to include the layout changes and fleet size into the consideration when configuring AGV flowpath network.

This study is organized into 7 parts as they appear in each chapter. In Chapter 1, research objective is addressed. Objective function is to minimize total cost of the system, which is based on transportation operating and system investment costs. Scope of the study is limited to production based facilities with a predetermined production requirements, and a set of processing stations with specific space requirements. The study focuses on unidirectional Automated Guided Vehicle system (AGVs) as they are widely used in recent manufacturing systems. Formulation of network configuration problem including layout, flowpath and fleet size configuration is discussed.

In chapter 2, previous studies on the problem are reviewed according to three main sub-problems- machine layout, flowpath network configuration and AGV fleet size. A number of researches have been conducted on machine layout with a given simple flowpath network. Most of the studies used flow-distance based decision variable for the selection of solution. A number of studies also focused on flowpath network configuration with uni-directional based transporter. However, these studies assumed that machine layouts were given, and remained fixed throughout the considerations. Studies on AGV fleet size problem had been considered separately from the first two sub-problems. Many studies on fleet size problem suggested analytical techniques to estimate fleet size requirement, and subject to further simulation for more accurate number. Decision variable based mainly on loaded transportation distance, which is the production of flow volume and shortest distance between stations.

Chapter 3 is devoted to problem description, mathematical expression of the problem, and the proposed solution procedure. The problem is defined using three types of variable, distance, time and cost based. Main objective function is expressed as a total cost basing on operating time and investment cost of AGVs. Operating time is addressed as a major decision variable and expressed with three components. They are loaded transportation, empty transportation, and AGV blocking times. It has been found that the problem is a very difficult combinatorial problem due to large amount of variables involved. A two-stage approach is proposed to solve the problem. The first stage, static analysis, searches for a potential best solution by considering only volume-distance of material handling. The best solution from the static stage is used as an initial solution for the second stage, dynamic analysis, where other production requirements and number of AGV are taken into consideration.

In chapter 4, the proposed static stage is further described. An integration of modern heuristic based algorithms, Simulated Annealing (SA) and Genetic Algorithm (GA), is presented. SA is used to search for machine layout solutions, while GA is simultaneously used to search for flowpath configurations. A unique string to represent flowpath solution is proposed. A string consists of a number of bits corresponding to number of arcs in the system. Each bit is filled with 0,1 or −1, when 0 represents the existing of an arc, 1 or −1 represents
the arc’s direction. Two GA operations, mutation and crossover, are used for neighboring a flowpath configuration. Feasibility of a solution, and a technique used to check for feasibility, are discussed.

In chapter 5, details of the dynamic stage are described. Layout and flowpath configurations are represented by mathematical expressions in a simulation model. Characteristics of queue, production and AGV dispatching rules are determined. AGV’s collision is avoided by the concept of zone controlling. An idle AGV is directed to a home position, where it is staged until it is allocated to the next transportation request. The system is constrained by an average number of Works in Process (WIP). The calculation of the time components in the main objective function, as described in chapter 4, is explained. A two-stage heuristic, flowpath and layout alternative, to search for a better solution is proposed.

In Chapter 6, numerical experiments are conducted on two main purposes. The first purpose is to set GA and SA’s parameters before the proposed algorithms can be able to apply to the problems. It can be found that both GA and SA are effective in solving problems basing on specific range of parameters. The second purpose is to demonstrate the solution procedure and to verify the performance of the proposed algorithms. In stage I, the layout-fixed and layout-changed algorithms can be able to produce optimal solutions for small-sized problems compared to known optimal solutions from literature. For large-sized problem, the algorithms are effective and efficient in improving solution quality. In stage II, effects of dynamic condition from AGV fleet size to the flowpath and layout solution can be seen from the experiments. The proposed heuristics are effective in improving solutions.

Finally, conclusion is drawn in chapter 7. A network configuration with the consideration of layout changes provides a better solution than the one with layout-fixed condition. Moreover, number of AGV in the system has a significant effect on the network configuration. It has been found from the experiments that the proposed algorithm is effective and efficient in searching for a better solution. The improvement of solution quality is significant with reasonable computation time.

This study has two folds of advantage. Firstly, it is a decision-making tool for layout planners in configuring flowpath network of material handling for production facilities. The study provides the planners with the layout-changed algorithms, which have never been considered in any previous studies. Secondary, it is a design tool for AGV system designers in configuring the system’s flowpath network and fleet size. It also provides the designers with insight information on the dynamic condition of the designated systems.