



An Ant Colony Algorithm (ACA) for solving the new integrated model of job shop scheduling and conflict-free routing of AGVs



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ABSTRACT

This paper concerns with the Job Shop Scheduling Problem (JSSP) considering the transportation times of the jobs from one machine to another. The goal of a basic JSSP is to determine starting and ending times for each job in which the objective function can be optimized. In here, several Automated Guided Vehicles (AGVs) have been employed to transfer the jobs between machines and warehouse located at the production environment. Unlike the advantages of implemented automatic transportation system, if they are not controlled along the routes, it is possible that the production system encounters breakdown. Therefore, the Conflict-Free Routing Problem (CFRP) for AGVs is considered as well as the basic JSSP. Hence, we proposed a mathematical model which is composed of JSSP and CFRP, simultaneously and since the problem under study is NP-hard, a two stage Ant Colony Algorithm (ACA) is also proposed. The objective function is to minimize the total completion time (make-span). Eventually, in order to show the model and algorithm's efficiency, the computational results of 13 test problems and sensitivity analysis are exhibited. The obtained results show that ACA is an efficient meta-heuristic for this problem, especially for the large-sized problems. In addition, the optimal number of both AGVs and rail-ways in the production environment is determined by economic analysis.

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1. Introduction

In a basic Job Shop Scheduling Problem (JSSP), each job has several operations to be processed on some or all of the given machines Drobouchevitch and Strusevich (2000). Also in JSSP, the jobs have different processing routes. In other words, the processing route for each job differs with processing route of other jobs. In addition, the processing time for each job on each required machine is given. The purpose is to find a schedule which minimizes a given objective function. In initial papers, the transportation times between machines have not been considered. Their authors claimed that because transportation times are very small in comparison with the processing times, thus they are negligible. On the other hand, in recent decades, the more researchers have been attracted by some issues that the transportation times were considerable and ignoring of them impacts on optimal solution. The jobs can be transferred from a machine to other machine by various vehicles. For example truck, conveyor, crane, Automated

Guided Vehicle (AGV) or even a manpower and etc. can be used to move the jobs. Depending to the transportation vehicle selected in the production system, the different problems have been established in literature. For instance, the papers that trucks are used as transportation vehicle in the production environment differ with those AGVs are responsible to move the jobs. In other words, the using the AGVs inserts the new constraints into problem such as conflicts constraints, pre-determined routes constraint, battery drain constraint and so on so that the complexity of such problems increases extremely. Therefore, if AGVs are not managed efficiently, they would be able to fail throughout the production system. For example, when two AGVs collide with each other along the routes, the system is stopped and undergoes the high costs. In such conditions, applying the Conflict-Free Routing Problem (CFRP) for AGVs will control the collision of them and keep the system alive (with high quality).

In here, a specific production system which is formed by a warehouse, several machines and a network guide-path has been considered. The network guide-path is the same embedded special rail for moving the AGVs in which these rails do not allow AGVs to move toward all directions. Moreover, there are number of jobs and AGVs in warehouse at the beginning of planning period. A schema of production system under study is shown in Fig. 1. Our

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purpose is both assignment and scheduling for jobs and then to find free-conflicts routes so that make-span as objective function is minimized.

The remainder of this paper is organized as follow. Section 2, includes a review of the literature and discussion of issues developed for JSSP subject to transportation times between machines. In Section 3, the JSSP considered in this paper is described and in Section 4, the considered problem is formulated. Section 5, describes proposed two stage ACA for solving this problem and in Section 6, the developed economic analysis is described. Also, in Section 7, several test problems are generated to determine model and algorithm's efficiency. Furthermore, sensitivity and economic analysis are examined in Section 7. Conclusion and future research for this study is provided in Section 8.

2. Literature review

Johnson's paper in 1954 was the first paper which established the production scheduling problem with considering the transportation times between machines. In this paper, he considered a flow shop with two machines. Then, many researchers presented the various papers by using his idea. For instance, Raman (1986) developed the Johnson's problem with more number of machines. Also Behnamian, Fatemi Ghomi, Jolai, and Amirtaheri (2012) established a mixed integer programming model and proposed a heuristic algorithm based on the basic idea of Johnson's algorithm in order to minimize of make-span in a three-machine flow shop scheduling problem. In their study, a batch processing machine was located between two single processing machines on first and third stages. They also proposed a Genetic Algorithm (GA) and compared it with heuristic. They demonstrated the ability of GA to find the better solution. The job shop scheduling problem was very more complicate when it was compared with flow shop scheduling and this is why researchers have paid special attention to these areas. For example, Lacomme, Moukrim, and Tchernev (2000) proposed a branch-and-bound coupled with a discrete event simulation model in a job shop with one AGV. They focused on the job-input sequencing problem to determine the order in which the jobs enter the manufacturing system by branch-and-bound and then job sequence under given vehicle and machine dispatching rules was evaluated by a discrete event simulation. In their paper, AGV moved by several different vehicle dispatching

rules. In other paper that job-shop has been considered as a production system, Blazewicz, Burkard, Finke, and Woeginger (1994) presented an algorithm which consists of two steps to solve the scheduling and the routing problem separately. They also used dynamic programming to check whether an AGV is enough to transfer all jobs in determined time horizon. They established a new method to prevent conflict of AGVs. Khayat, Langevin, and Riopel (2006) also considered a job shop. They used shortest path rule between two machines for a material handling operation. In this paper, a mathematical programming model and a constraint programming model are presented for the problem and then they implemented it on several available test problems in the literature. The performance of the two methods was compared and they concluded that for larger instances the performance of the constraint programming model was superior to the mathematical programming model.

In 2006, decomposition methods were developed for solving of such problems. Of course, because number of variables for these problems is very high, the conventional decomposition methods were not able to solve these problems. Therefore, researchers used decomposition methods together with kinds of cut generations methods. For example, Dogan and Grossmann (2006) used the logic-based Benders decomposition method which was introduced by Hooker in 2003 to solve the simultaneous planning and scheduling problem. This paper addressed a bi-level decomposition algorithm for the simultaneous production scheduling and routing for the vehicles with conflict-free path selection. Hamana, Konishi, and Imai (2007) presented a job-shop with AGVs and production processes. In this problem, sequence of production process was given beforehand. Also, transportation guide-paths were network-formed which node was place that AGV could stop or turn, and edge as AGV's route was connecting route between nodes. Two constraints were added to avoid collisions: (1) two AGVs could not place on a node in the same period, (2) two AGVs could not travel on an edge at the same time period. To solve this problem, they applied logic cut algorithm which is decomposed to the master problem and sub problem. Production schedule and assignment of request to AGV was solved in the master problem and transportation routing was solved in the sub problem regard to minimizing of make-span. Nishi, Hiranaka, and Grossmann (2011) developed a bi-level decomposition algorithm for simultaneous scheduling and routing. Master problem solved scheduling

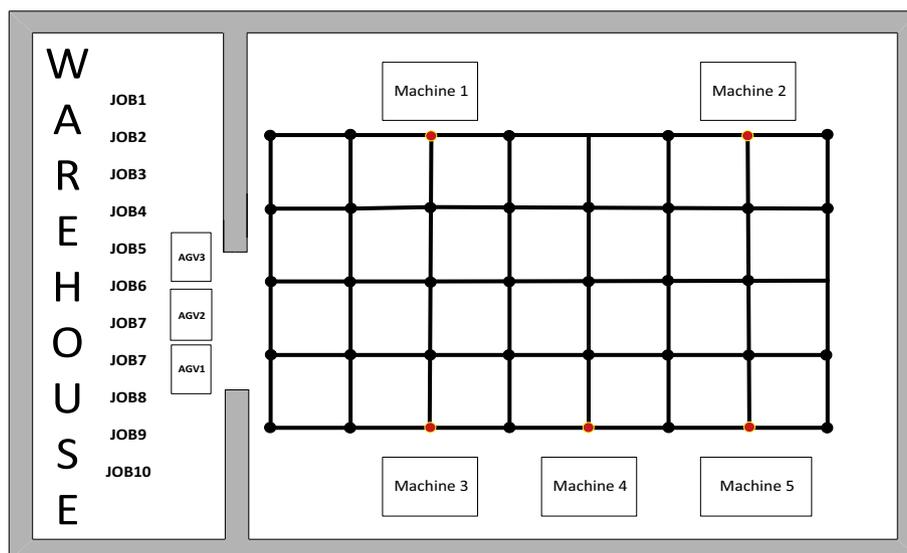


Fig. 1. A schema of production system under study.

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