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RESEARCH PAPER

The Optimal Area Covered with A Single autonomous guided vehicle using Humanized Computing

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ABSTRACT

The area coverage of machines on the production line to address the scheduling and routing problem of autonomous guided vehicles (AGV) is an innovative way to improve productivity in manufacturing enterprises. This paper proposed a new model for the optimal area coverage of machines in the production line by applying a single AGV to minimize both the transfer costs and the number of breakpoints of AGV. One of the unique advantages of the area coverage employed in the present study is that it minimizes transfer costs and breakpoints, and makes it possible to provide service for several machines simultaneously since the underlying assumption was finding a path to ensure that every point in a given workspace is covered at least once. Since rail AGV is used in this study, AGV can only pass horizontal and vertical distances in the production line. The reversal of the AGV path in vertical and horizontal distances implies failure and breakpoint in the present paper. The simulation results confirm the feasibility of the proposed method.

KEYWORDS: Autonomous guided vehicles (AGV); Regional coverage; Failure; Horizontal distances; Vertical distances.

1. Introduction

Technological innovations in autonomous vehicle-based systems are geared towards achieving greater operational efficiency and flexibility that would be necessary for the further development of modern industries. Before the Industrial Revolution, humans carried out their work with the power of their arms and without the use of any automation technology. With the onset of the Industrial Revolution, there was a growing trend in technology and the construction of machines and vehicles that saved humans from repetitive, tedious, and sometimes even dangerous tasks. AGVs are material handling machines used for the transports of pallets (goods and materials) in distribution areas, such as industries, warehouses, cross-docking canter's, and container terminals, and etc. to optimize the productivity and efficiency in materials handling tasks because of their specific advantages and benefits, which include the increase of flexibility in processes, low labour costs, 24-h availability (depending on the battery's charging time), and computer integration and management of the handling operations Intelligent [1,2]. The number of AGVs required for the execution of the tasks and the existence of an efficient task scheduling and routing system is main factors that must be examined for the implementation of an AGV system so as not only to minimize the time spent but also to avoid collisions and deadlocks [3, 4, and 5]. Bish et al. (2005) defined the primary AGV management functions as: 1) Dispatching function that is the selecting and assigning of tasks to vehicles. 2) Routing function that is the selection of the

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specific paths taken by vehicles to reach their destinations. 3) Scheduling function that is the determination of the arrival and departure times of vehicles at each segment along their prescribed paths to ensure collision-free journeys [6]. In this paper, the focus was on the routing problem which includes the selection of the specific paths taken by AGVs to reach destinations. There are several indicators for evaluating the AGVs routing [7].The primary is to attenuate the whole travel distance of AGVs, which can not only convey the tasks to the destination as early as possible but also reduce the energy consumption of AGVs. The second is to minimize the breakpoint of AGVs workload, which can ensure capacity equalization and avoid resource waste. The third is to minimize the predicted delivery time of tasks, which can ensure the stability of the production process to improve production capacity in the industrial production. Although the analysis of the routing problems started in the early 80s [8], new approaches related to the minimization of AGV routes in industrial applications have been proposed in recent years [7]. The main problem regarding the obtaining of an AGV control of satisfactory performance is the determination of the optimal number of vehicles to attend all tasks on time with a sufficient number of vehicles [5]. Conventional goal-oriented and map-based path planning methods, artificial potential field (APF), cellular decomposition, template based, sensor-based, neural networks and fuzzy logic are among various approaches to exhaustive and random coverage path planning [9].This paper proposed a new model for the area coverage of machines in the production line by applying a single AGV to minimize both the transfer costs and the number of breakpoints of AGV. Since rail AGV is used in this study, AGV can only pass horizontal and vertical distances in the production line. The reversal of the AGV path in vertical and horizontal distances implies failure and breakpoint in the present paper. The main contributions of this paper are summarized as follows: (1) the transfer costs and breakpoint are minimized so that the total travel distance of AGV and the objective value are reduced. The tasks can be delivered in a shorter period of time. As a result, the production cost is reduced and the production efficiency and productivity are improved. (2) The area coverage model proposed in this paper can be used in other manufacturing enterprises. The proposed model aimed to develop a more efficient model considering the advantages and shortcomings of previous studies.(3) In all the articles mentioned, the machines to which the AGV is assigned include one point, and the AGV must be assigned to this point, and this is a problem that no article has mentioned so far, or less It has been noted that considering a quadrilateral for each machine and AGV to each one of the points of this in all the articles mentioned, the machines to which the AGV is assigned include one point and the AGV must be be assigned to this point, and this is a problem that no article has mentioned so far or has paid less attention to, considering a quadrilateral for each car, and AGV to each one of the points of this car that It is sufficient to be assigned. The machine that is assigned is sufficient. All the articles mentioned, the machines to which the AGV is assigned include one point and the AGV must be assigned to this point and this is a problem. Which no article has mentioned or paid less attention to, considering a quadrilateral for each car and AGV is enough to be assigned to each one of the points of this car.

The remainder of this paper is organized as follows. In Section 2, previous studies related to this study are reviewed. In section 3, mathematical modeling and model hypotheses are comprehensively discussed. The AGV is described in detail through an illustration of the manufacturing and the proposing mathematical model of this problem. In Sect. 4, a numerical example is provided. Then, the comprehensive criterion method is used according to the weights of the objectives to achieve the most accurate optimal solution. In Sect. 5, the results are analysed and the conclusions discussed. In Sect. 6, future researches are provided.

2. Literature Review

Automatic Guided Vehicles (AGVs) are material handling machines traveling on a network guide path (Fazlollahtabar et al. 2015; Ho et al. 2012; Nouri et al. 2016) [10,11,12] that can be interfaced to various other production and storage machines [13]. The AGV vehicle is a guided vehicle or mobile robot and is guided by wire markers, tape, optometry, or laser. An efficient AGVs scheduling will increase the productivity and reduce the delivery cost [14]. Nowadays, a large number of AGVs are employed to carry out repeating transport tasks in many manufacturing and warehouse industries. Their intensive application is influenced by many vital factors of apparatus expense, vehicle manoeuvrability, energy potency, and configuration flexibility, particularly in an exceedingly large-scale AGV system. Intelligent transportation systems square measure won't to increase productivity and cut back the transportation costs in producing enterprises. The first AGV in the world was developed by Bart Electric Company in 1953, which was mainly used to control the grocery store [15]. Until the mid-seventeenth century, AGV systems grew rapidly so that there were more than 100,000 AGVs in the nineteenth century [16]. AGVs are commonly used for material transportation in distribution, warehousing, and factory systems. Among automated transportation systems, AGV systems can be integrated with other systems, are more economical and flexible in capacity and the path, and have environmental benefits that make them of particular importance [17, 18]. Models based on a single AGV are often used in small industries and small factories, and the use of models based on multiple AGVs in large industries can also be studied. The problems existing in the operation to make the system in line with the requirement of the administrator. The multi-AGVs management problem is a multi-objective, multi-constraint combinatorial optimization problem, which depends on the types of application scenarios. Considering different dimensions of the problem, the multi-AGVs management system is first studied from three perspectives, namely, 1) task dimension dispatch, 2) spatial dimension-path, and 3) time dimension-scheduling. Comparison of the three dimensions and their respective solutions are discussed in detail as well. Secondly, considering their utility, the multi-AGVs management problems are divided into three categories: 1) cost reduction, resource-oriented, 2) efficiency improvement, problem-oriented, 3) personalized demand, goal-oriented.

AGVs are battery-powered and manned machines that are programmed to select routes and positions so as to respond quickly to changes in transmission patterns. They can be integrated into automated manufacturing systems. The AGV option is more durable than other material handling systems to increase productivity due to lower manpower costs and improvement of system flexibility [19]. AGV systems are robots that require the cooperation of all types of AGVs to perform material handling tasks.

Routing planning is an important issue in AGV systems that aims to minimize the time traveled or the travel distance [20]. The main focus of researchers is on the route planning of AGV and improving system performance [21,22].AGV scheduling can be divided into online and offline scheduling. In some research, some important factors such as limited input and output, buffer capacity, random arrival, preparation of the work pieces, maximum time, etc. are taken into account in adapting the types of algorithms to solve the model. A multiple decision support system to weigh each criterion for AGV selection was introduced [22]. In fact, they ranked the options to select the appropriate AGV using the fuzzy TOPSIS method. A rational process for selecting the appropriate AGV for the production environment according to its applications was proposed [23]. This process was based on the Preference Selection Index (PSI), which evaluates and ranks the options, then the results of this process were compared with the TOPSIS method. A new approach to solve the problem of heterogeneous AGV routing by considering energy consumption (EHARP) was proposed [20]. The PSO (particle swarm optimization) algorithm was used to solve the problem. It was assumed that the shorter the distance, the better the planning route while in previous studies the goal was only to minimize the distance. A distributed routing method under motion delay disturbance was proposed in which some unexpected disturbances such as motion delay sudden transfer requests, which increases total time were considered. The optimal path in an automated guided vehicle (AGV) routing problem network considering triple criteria of time, cost, and capacity was studied [10]. This paper aimed to determine an optimal route for a single AGV in a production line containing several machines so that it covers all machines by considering two criteria of minimizing transfer cost and breakpoints. A district coverage operation as a route planning program requiring a robot to cover every part of the workspace was employed [24]. A new solution to the problem of optimal regional coverage based on a genetic algorithm to obtain the best path was proposed [9]. The simulation results of their proposed model confirm the feasibility of the method. A new memetic algorithm (MA) as a genetic algorithm (GA) that combines the global and local search was proposed to optimize the partitioning problem of tandem AGV systems. It aims to minimize the maximum AGVs' workload to balance the workload among all the zones and avoid the presence of bottlenecks [25]. A harmony search-based memetic optimization model was proposed to handle the production and transportation scheduling problem in a make-to-order (MTO) supply chain and certain heuristic procedures were proposed to convert the investigated problem into an order assignment problem [26]. A computer-integrated manufacturing system was designed to identify an optimal path in an automated guided vehicle (AGV) routing problem network, special case for vehicle routing problem (VRP) considering triple criteria of time, cost, and capability in decision making, simultaneously [10]. A comparative study between three approaches of the Dijkstra algorithm, Genetic algorithm (GA), and a heuristic method was made to handle routing, assignment, and scheduling problems of containers to AGVs [27]. A new approach to plan the facility layout of the investigated AGV-based modular prefabricated manufacturing system was proposed [28]. An optimization method for the size arrangement of the workstation area and the storage area was developed to minimize the production time and maximize the workstation utilization. A non-dominated sorting genetic algorithm simulation is designed to solve the model. Then, a heuristic method to direct the placement, reshuffle, and retrieval of the modular prefabricated products in the storage area was used. A multi-objective mathematical model of AGV scheduling and an improved harmony search (HS) algorithm was proposed by considering rate (HMCR) parameters and implementing a neighbourhood search strategy for the best harmony in harmony memory (HM) to reduce the total travel distance of AGVs, the objective value, and the production cost [29].A new method based on inference search (IS) algorithm was developed for optimizing scheduling and minimizing mean tardiness in identical parallel joint robots [30]. Results indicated that the proposed method, unlike genetic algorithms (GA), tabu search (TS) algorithms, and hybrid intelligent solution system (HISS) was scalable and it optimized the parameters of mean tardiness and system solution time. A multi-objective mathematical model of AGV scheduling with three objectives, i.e., the total travel distance of AGVs, the standard deviation of AGVs workload and the standard deviation of the difference between the latest delivery time and the predicted time of tasks was used. Then, an improved harmony search (HS) algorithm was proposed for the best harmony in harmony memory (HM) [31]. The inference search (IS) algorithm was proposed as a new model for scheduling and minimizing mean tardiness in identical parallel joint robots. Unlike genetic algorithms (GA), tabu search (TS) algorithms and hybrid intelligent solution system (HISS), the proposed model was scalable and more successful to optimize the parameters of mean tardiness and system solution time [30]. A novel parallel algorithm for multi-AGV warehousing systems was employed for task assignment, path planning, and vehicle navigation [32]. Various practical simulations were conducted to examine the efficiency and robustness of the new algorithm.

3. Methodology

The area coverage in the present paper implies that the machines are assumed to be located in a specific area to be serviced by a single AGV. It is sufficient for the AGV to visit at least one point of a machine to be regarded as the server of that machine. In fact, machines are considered as areas and zones here. If machines are to be considered as points, modelling would be a traveling vendor problem to find the optimal path that starts at the desired point and ends at that point. Modelling for such problems is not difficult in which the machines are assumed to be points. Since the machines were considered as areas in the present study, modelling must be done differently. Area coverage modelling in the present study was inspired by point coverage with a few changes. The AGV starts giving services from one point of a machine (No starting points is considered for the model. The solution of the model gives the optimal path and each point in the optimal path can be considered as the starting point) and after passing a closed path, returns to the same point of the machine, i.e. in this case it is enough for the AGV to visit at least one point of the rectangular area to covers the path. . In area coverage, an AGV may cover two or more a machines simultaneously (at one point), whereas in point coverage this was not possible. This is one of the major benefits of area coverage, which can save a lot of time, energy, and money in factories. Figure 1 clearly shows this. Figure 2 shows a picture of a rail AGV.

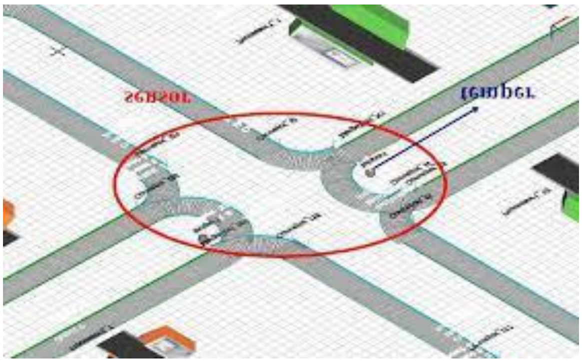

Fig. 1. Area coverage of AGV

Fig. 2. A rail AGV

Figure 3 shows several machines and an area for holding AGVs, and the machines are scattered in a rectangular area throughout the factory environment.

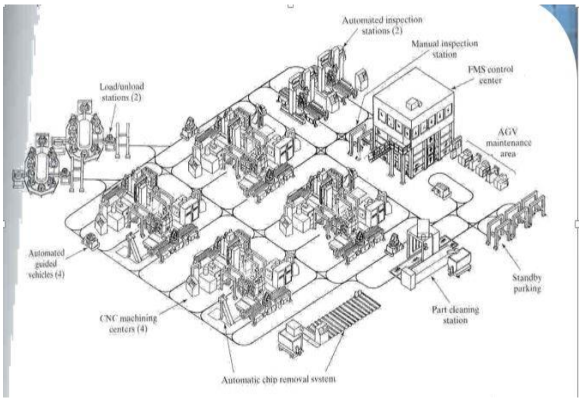

Fig. 3. Regional coverage of AGV in which machines have been considered as the areas

In Figure 4, every 10 machines is considered as a rectangle (area). The blue route covers "one point of cars 1, 3 and 5", "2 points of cars 2 and 4" and aims to determine the number of these routes so that a circle is formed and all machines are covered. Failure occurs when the end of this blue path changes its direction vertically. The two yellow points in Figure 5 are the breakpoints**.**

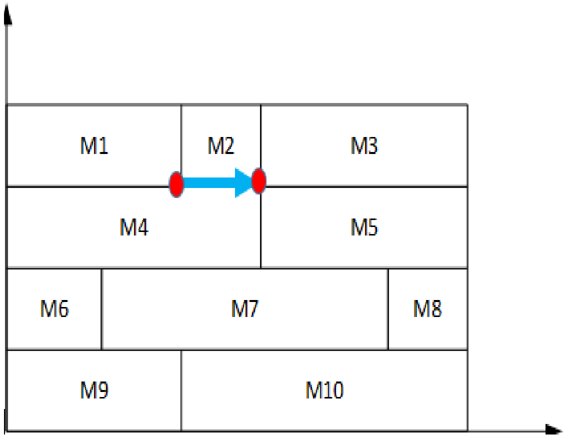

Fig. 4. Top preview of a factory with 10 machines with a single AGV

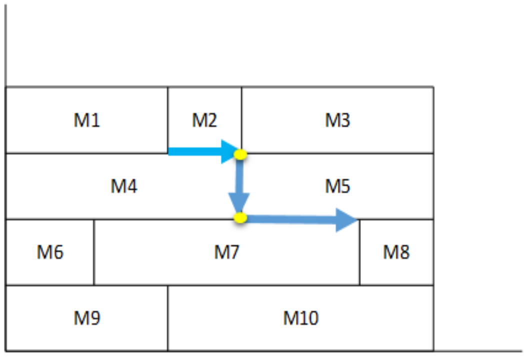

Fig. 5. Top preview of top preview of a factory with 10 machines with a single AGV and display of breakpoint

3.1. Main assumptions

1) Machines are considered as areas and zones. (As a rectangle).
2) If at least one point of the device is located in the AGV path, that device is covered by the AGV.
3) The breaking point is defined as follows: When a path direction changes its direction in a loop, a failure occurs.

Indexes

i :Index along the axis x $i = 1,2, \dots, X$

j: Index along the axis y $j = 1,2, \dots, Y$

Parameters

$C_{iji'j'}$: Transfer cost from point (i, j) to point (i', j')

$d_{iji'j'}$: distance from point $(i, j) to\ point\ (i', j')$

$x_{iji'j'}$: If there is a direct connection from $(i, j)\ to\ \left(i', j'\right) = 1, otherwise\ 0$

M: Total machines

Variables

$Z_{iji'j'}$: If AGV moves (i, j) to$\left(i', j'\right) = 1\ , otherwise = 0$

3.2. Mathematical model

$Min: Z_1 = \sum_i \sum_j \sum_{i'} \sum_{j'} C_{iji'j'} * d_{iji'j'} * Z_{iji'j'}$ (1)

$Min: Z_2 = \sum_i \sum_j \sum_{i' \neq i} \sum_{j' \neq j} Z_{ijij'} * Z_{ij'i'j'} + \sum_i \sum_j \sum_{i' \neq i} \sum_{j' \neq j} Z_{iji'j} * Z_{i'ji'j'}$(2)

Subject to:

$\sum_{i'} \sum_{j'} Z_{iji'j'} \leq 1 \qquad \forall\ i, j$ (3)

$\sum_i \sum_j Z_{iji'j'} \leq 1 \qquad \forall\ i', j'$ (4)

$\sum_{i'} \sum_{j'} Z_{iji'j'} * x_{iji'j'} \geq 1 \qquad \forall\ i, j \in M$ (5)

$Z_{iji'j'} \leq x_{iji'j'} \qquad \forall\, i, j, i', j' (6)$
$\sum_{i'} \sum_{j'} Z_{iji'j'} = \sum_{i'} \sum_{j'} Z_{i'j'ij} \qquad \forall\, i, j (7)$
$Z_{iji'j'} + Z_{i'j'ij} \leq 1 \qquad \forall\, i, j, i', j' \ (8)$
$\sum_{i} \sum_{i'} Z_{iji'j'} \geq 1 \qquad \forall\, 1 < j < X - 1\,,\ j' = j + 1 \ (9)$
$\sum_{j} \sum_{j'} Z_{iji'j'} \geq 1 \qquad \forall\, 1 < i < Y - 1\,,\ i' = i + 1 \ (10)$
$Z_{iji'j'} \ \ binary \quad (11)$

Equations
Equation (1) is the first objective function that calculates the amount of the transfer cost.
Equation (2) is the second objective function which expresses the number of failure points.
Equation (3) states the movement can be made from one point to maximally one another point (maximum of one output from one point).
Equation (4) states the number of points that can be reached to a certain point is maximally one point. (Maximum of one input to each point).
Equation (5) states that the AGV must pass through at least one point in each machine.
Equation (6) states that it can be possible to go from one point to the next one only if there is a path.
Equation (7) states that the number of inputs to a point is equal to the number of outputs from that point. Equation
(8) Between two adjacent points, there is at most one path in the loop (if there is a path in the loop).
Equations (9) and (10) express the limitation of the single-loop AGV pathway.
The intersection of each side of a rectangle with the x and y axes is denoted by the set i and j, respectively.
The relations 5-6-9-10 are the relations that express exactly the problem of polygonal cars and the existence of a loop in the whole route, and they are new formulas that are used in this article.

4. Numerical Example

Suppose there are 10 machines, each of which is shown as a rectangle. The AGV path is to be defined (optimally) so that at least one corner point of each rectangle (rectangle) is covered. There are also two objectives:
1) Minimizing the transfer costs.
2. Minimizing the number of break points.
The cost of moving from one point to another is also taken fixed at ($C_{ij} = 25$)and the distance of i points from each other as well as the distance of j points from each other equal 2 meters. (Figure 6).

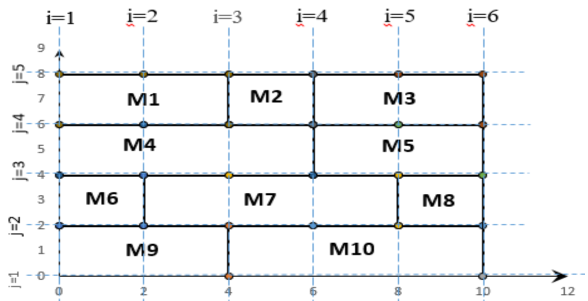

Fig. 6. Top preview of the machines in the factory with the display of the length and width of the machines.

If the first objective function is put in priority 1, the problem is solved and the optimal answer is equal to:
$Z_1 = 600\ \$$
$Z_2 = 8$
$Z_{1323} = 1$
$Z_{2322} = 1$
$Z_{2232} = 1$
$Z_{3242} = 1$
$Z_{4252} = 1$
$Z_{5253} = 1$
$Z_{5343} = 1$
$Z_{4344} = 1$
$Z_{4434} = 1$
$Z_{3424} = 1$
$Z_{2414} = 1$
$Z_{1413} = 1$

Assuming that the starting point is (1, 3) (the starting point has no effect on solving the problem), and the value of Z_{1323} is equal to one, so there is a path from point (1, 3) to point (2,3) (i.e. from There is a path from points $i = 1, j = 3$ to points $i = 2, j = 3$ (yellow path in Figure 7). The value of Z_{2322} is equal to one, so there is a path from point (2, 3) to point (2,2). (Blue path in Figure 8) (The first failure occurs at this point because the direction has been changed from horizontal to vertical.) Regarding other variables in the optimal answer, the optimal path is as what is shown in figure 9.

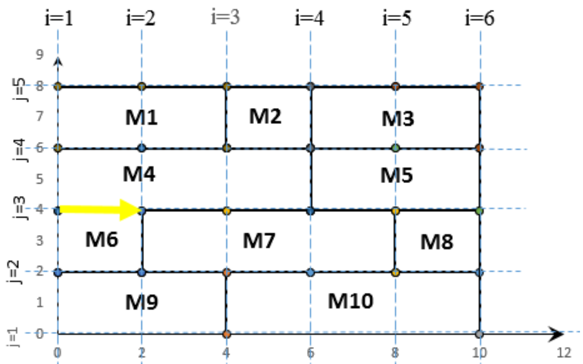

Fig. 7. Display of the yellow path according to $\mathbf{Z_{1323} = 1}$

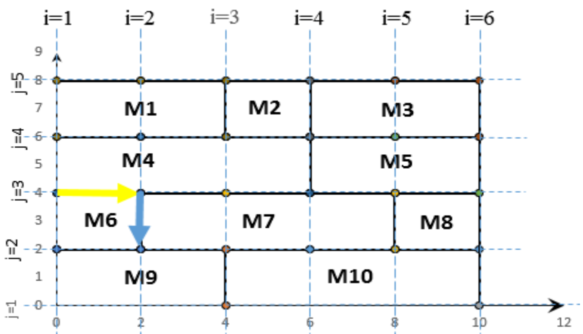

Fig. 8. Display of the blue path according to $\mathbf{Z_{2322} = 1}$

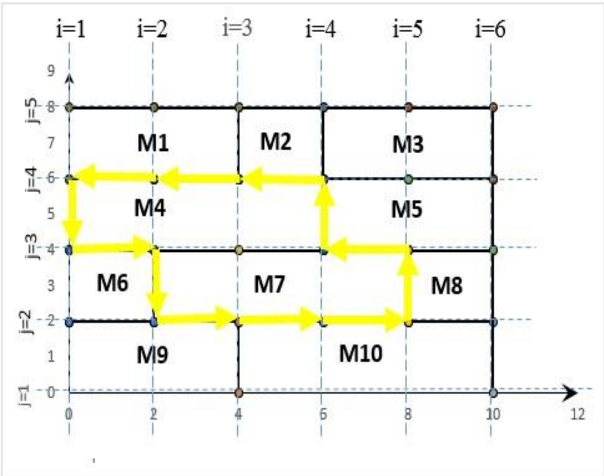

Fig. 9. The optimal loop of the problem regarding the first objective function as the priority 1

If the second objective function is put in priority 1, the problem is solved and the optimal answer is equal to:

$Z_2 = 4$
$Z_1 = 700$
$Z_{1312} = 1$
$Z_{1222} = 1$

$Z_{2232} = 1$
$Z_{3242} = 1$
$Z_{4252} = 1$
$Z_{5262} = 1$
$Z_{6263} = 1$

$Z_{6364} = 1$
$Z_{6454} = 1$
$Z_{5444} = 1$
$Z_{4434} = 1$
$Z_{3424} = 1$
$Z_{2414} = 1$
$Z_{1413} = 1$

Regarding previous explanation, the optimal AGV path is as what has been shown in Figure 10.

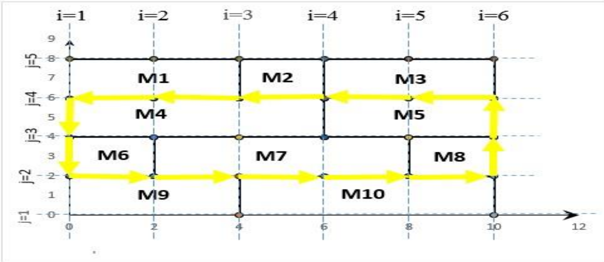

Fig. 10. Optimal problem loop with respect to the second objective function as priority 2

4.1. Using the global criterion method

The global criterion method seeks to solve the problem in such a way that the difference between each objective function and its optimal value is minimized. The formula that expresses such an issue is known as the "LP-Metric" method, and it is applied when no information is required to get from decision makers. In the general, the formula of LP-Metric which is known as compatible functions can be defined as follows:

$$L - p = \left[\sum_{j=1}^{k} \gamma_j \left[\frac{f_j(x_j^*) - f_j(x)}{f_j(x_j^*)}\right]^p\right]^{\frac{1}{p}}$$

Define the parameters:
x_j^* : Indicates the ideal solution for optimizing Objective.
x : indicates a hypothetical solution.
γ_j: Indicates the degree of importance for goal jth objective.
$L - p$: indicates minimizing the deviations from the ideals that should be minimized.
p: indicates a value or degree that the larger it is, the more emphasis will be placed on the largest deviations. Therefore, for the objective function problem, it is expressed as follow: $\gamma_1 = 5$, $\gamma_2 = 1$, $p = 1$

$$min: \ Z = 5 * \left[\frac{600 - Z_1}{600}\right] + 1 * [\frac{4 - Z_2}{4}]$$

Subject to: constraints 3 to 11
The optimal answer equals:

$Z = 0.5$
$Z_2 = 6$
$Z_1 = 600$
$Z_{2434} = 1$
$Z_{1424} = 1$
$Z_{1314} = 1$
$Z_{4353} = 1$
$Z_{4443} = 1$
$Z_{3444} = 1$
$Z_{4232} = 1$
$Z_{5242} = 1$
$Z_{5352} = 1$
$Z_{1213} = 1$
$Z_{2212} = 1$
$Z_{3222} = 1$

The optimal path is shown in Figure 11.

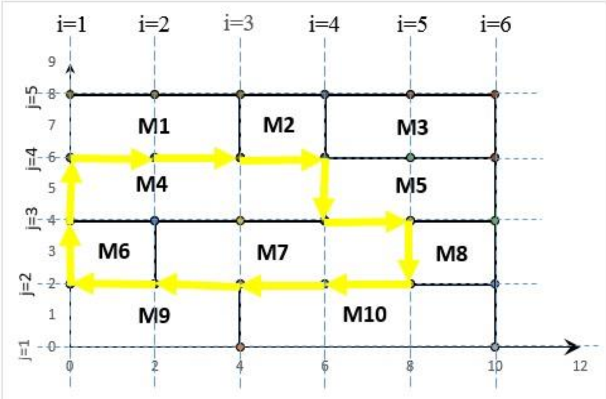

Fig. 11. Optimal problem loop with respect to the global criterion method

As the dimension of the problem increases and the generation of random data, as seen, the solution time increases, and in larger dimensions, the use of heuristic and meta-heuristic algorithms is recommended, which can be one of the future studies of using heuristic and meta-heuristic methods for solve the problem.

Tab. 1. Increasing the dimensions of the problem and the solution time

Row	i	j	solution time
۱	6	5	0.016 SECONDS
2	10	8	25 second
3	12	10	1 minute
4	14	16	5 minute
5	20	20	20 minute
6	25	25	1 hours
7	30	30	> 1 hours

5. Conclusion

The present study attempted to propose a new approach to the regional coverage of machines on the production line to address the routing problem of autonomous guided vehicles (AGV). The problem modelling was relatively complex considering the transportation costs and breakpoints. In comparison to, the problem takes more time to be solved, but it has advantages such as minimizing the transfer costs and the number of breakpoints. The optimal route obtained from the model significantly decreases the costs associated with the AGV route as well as the service time of each AGV. The results showed that the optimal solution of the problem was a loop in which the AGV started giving service from one point and returned to the same starting point (no starting point was considered for the model since the model solution gives the optimal path and any point on the optimal route can be considered as the starting point) to firstly minimize the transfer costs of moving the AGV from one point to another and secondly to reduce the number of breakpoints in the coverage of all machines. The results also indicated that the final solution of the model was strongly dependent on the parameters of the model and it was very sensitive to them. The proposed model of this paper is additionally applicable to alternative cases within which additional machines and AGVs are required to be used. The main contributions of this paper are summarized as follows: (1) the transfer costs and breakpoint are minimized so that the total travel distance of AGV and the objective value are reduced. (2) The tasks can be delivered in a shorter period of time. As a result, the production cost is reduced and the production efficiency and productivity are improved. (3) The optimal area coverage model proposed in this paper can be used in other manufacturing enterprises. It is also worthwhile to develop a more efficient model considering the advantages and shortcomings of the present one.

This article has many applications in the transportation industry and warehouse of factories and locating post offices in different cities, for example, this model can be used for locating post offices in different cities and also routing the transport agent to collect postal envelopes. be used In fact, in the M_i's model, the role of cities and each side of the optimal route can be one of the points of the post office, and this strategy will significantly reduce transportation and construction costs, which we will address in future studies.

6. Future Research

Further studies can pave the way for more development in this area. The proposed problem of this paper is the regional coverage of machines in the production line of a manufacturing system focusing on the routing of a single AGV. The arrangement and number of machines were also taken into account. Considering the variety of AGVs, the possibility of applying multiple AGVs or increasing the number of machines in the production line as well as the diversity of arrangement, routing, and scheduling of machines, further studies can be carried out which drastically change modelling and the optimal solution of the problem in general and even change the solution time of the model. In the case of applying multiple AGVs in manufacturing systems, the problem of scheduling and routing several AGVs with the proposed model can be studied in further studies. Since the main innovation of this article is area coverage, AGV routing for such problems can be studied further by those interested in this field.

7. Declarations

Ethics approval: Not applicable.
Consent to participate: The authors equally participated in the study.
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