# The Design of an AGV in the Manufacturing Cell

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*Abstract* – **An automated material handling system is a must for an automated production system. An AGV (automated guided vehicle) therefore is one of the promising carriers used in the production line as a link between stations. However, an algorithm for determination number of AGVs required to satisfy the production is not quite prevalent and sometimes it is complicated. This paper aims to demonstrate a calculation of AGV required and then to verify the result by a simulation program. It is found that this proposed methodology is very useful and applicable for an early stage design of AGV. In the study case with 15 stations and elapse time ranging from 7 to 233 minutes. The required number of AGV is 8 units with 87.76% utilization and 3.44 second system waiting time.**

*Keywords* – **AGV, Material Handling System, Simulation**

## I. INTRODUCTION

An automated guided vehicle are now becoming in attraction for an automated production line. Nowadays, many factories confront with labor shortage and expensive; consequently, any operation without human expertise requirement is most likely to be replaced by an automated operation. Material handling system is also a prime area for automation. Thus, an automated guided vehicle is designed to replace conventional system. To efficiently implement AGV system is not easy. It requires perfect combination of good hardware technology and well management. In the past decades, much work has been done in hardware areas such as controller, path and guidance technology and made considerable progress in AGV technology. On the other hand, management has not yet been progressed due to the complexity of the problem. In the design stage, the appropriated numbers of AGVs must be determined to satisfy the production requirement. Then scheduling and dispatching of AGV will be considered next. The number of AGV can be obtained by quantitatively computed and/or simulated. However, one must use appropriated criteria to make decision. Therefore, this paper demonstrates quantitative approach in design of automated guided vehicle in the manufacturing cell.

A number of literatures have been done in this area. A survey of algorithms for scheduling and routing of AGVs is published in 2002 [1]. The AGV track layout including number of AGV using hierarchical queuing network model is described in many literatures [2,3,4,5,6,7]. An optimal flow path design for unidirectional AGV system has been attempted by Kaspi [9,10]. The mathematical model is developed to optimize the result. Artificial intelligence technique is also another approach to be used in AGV assignment. The genetic algorithm was attempted in AGV dispatching for a flexible manufacturing system [13].

## II. METHODOLOGY

1) *Problem description*: One of the automobile spare-parts manufacturer plans to utilize AGV in automated manufacturing cells. In this particular production line is composed of fifteen stations and a central storage. The main function of the central storage is to keep small components for the fifteen production stations. There will be eighteen parts for the production lines which three stations need two parts and the remaining stations require one part. An AGV is therefore designed to transport set of work-parts from the storage to the stations and return back to the storage. Thus, each automated guided vehicles will service only one station at a time. If any work station requires the work-parts, an AGV will be called. The next available AGV will consequently load another set of work-parts from the storage and transport to this station. Once finish unloading, this AGV returns to the storage and waits for the next call. The layout of AGV path is unidirectional as sown in Fig. 1. The elapse time of each work-part is tabulated in Table 1. This elapse time is duration time before the next batch of work-parts must be arrived at the station. The average travel time, loading/unloading, and service time of an AGV is shown in Table 2. The cycle time of an AGV is 15.26 minutes. The number of trip required for each work-part must also be determined. As an example, part A has an elapse time of 71 minutes. Thus, the number of trips required to transfer equals to 60/71 (0.845) trips. The required number of transportation trips is calculated and tabulated in Table 3. The total number of transportation trips in one hour is 29.831.

Due to the fact that the elapse time of each work-part is varied; therefore, the requirement of AGV for loading/unloading is random. Then, the optimum number of AGVs must be identified and will be described next.

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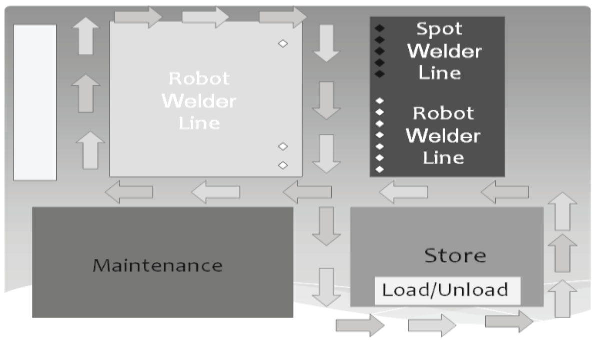


Fig. 1. The path layout of an AGV in the cell

TABLE1
The elapse time of work-part

| Station | Part | Elapse Time (min) |
|---|---|---|
| 1 | A | 71 |
| 2 | B | 22 |
| | C | 26 |
| 3 | D | 60 |
| | E | 62 |
| 4 | F | 7 |
| **5** | G | 121.4 |
| 6 | H | 95 |
| 7 | I | 27.3 |
| 8 | J | 62.3 |
| 9 | K | 220 |
| 10 | L | 30 |
| 11 | M | 26 |
| 12 | N | 233.3 |
| 13 | O | 30 |
| 14 | P | 116.4 |
| 15 | Q | 67.3 |
| | R | 53 |

TABLE 2
The activity performed by an AGV

| Activity | Average Time(min) |
|---|---|
| Travel time | 13.08 |
| Loading/Unloading time | 1.92 |
| Service time | 0.26 |
| Total | 15.26 |

TABLE 3
The number of trips required in an hour

| Station | Elapse Time (min) | Number of Trips per hour |
|---|---|---|
| 1 | 71 | 0.845 |
| 2 | 22 | 2.727 |
| | 26 | 2.308 |
| 3 | 60 | 1 |
| | 62 | 0.968 |
| 4 | 7 | 8.571 |
| **5** | 121.4 | 0.494 |
| 6 | 95 | 0.632 |
| 7 | 27.3 | 2.198 |
| 8 | 62.3 | 0.963 |
| 9 | 220 | 0.273 |
| 10 | 30 | 2 |
| 11 | 26 | 2.038 |
| 12 | 233.3 | 0.257 |
| 13 | 30 | 2 |
| 14 | 116.4 | 0.515 |
| 15 | 67.3 | 0.892 |
| | 53 | 1.132 |
| | Total | 29.831 |

2) *Problem solving*: As mentioned earlier, the number of automated guided vehicles must be determined. The solution can be obtained from (1).

$$N = \text{Maximum integer} \geq N_T \,/\, N_A \qquad (1)$$

Whereas

N= number of AGVs required; $N_T$ = number of transportation required (trip/hour); $N_A$ = number of trips per AGV per hour

In this study case, the total number of trips requested from 15 stations equals to 29.831 trips per hour. An automated guided vehicle will take 15.26 minute to complete one trip. Thus the AGV can serve 60/15.26 (3.93) trip per hour. Then substitute $N_T = 29.831$, $N_A = 3.93$ in (1)

Thus

$$\begin{aligned} N &\geq 29.831/3.93 \\ &\geq 7.587 \\ &= 8 \end{aligned}$$

As a result, the minimum number of automated guided vehicles will be at least eight cars. In order to explore other alternatives, the simulation software named ARENA will be utilized to view various results. Thus, various numbers of AGV are included in the simulation. The schematic layout of the manufacturing cell in the simulation model is shown in Fig.2. Distance between stations in the cell is shown in Table 4. Note that distance between some stations is zero this is due to the fact that the position of the stations is opposite each other. The number of trips as a result from the simulation program is shown in Table 5. It can be seen that the total number of 246 trips can be served when the number of AGV is greater than 6 units. The waiting time in the production line and the utilization of an AGV is shown in Table 6. These two measurements will be used later in decision making.

## III. RESULT

The result from the simulation program is depicted in Fig3. It can be seen that waiting time of the system is minimum when a number of automated guided vehicle is greater than eight units. On the other hand, the more number of AGV in the system, the less utilization of the machine. Then, the criterion is that the factory should maintain at least 80 percent utilization of the machine. Consequently, eight units of AGV with 87.76 percent and waiting time of 3.44 second is more promising than nine units with 78.01 percent utilization and waiting time of 1.62 second.

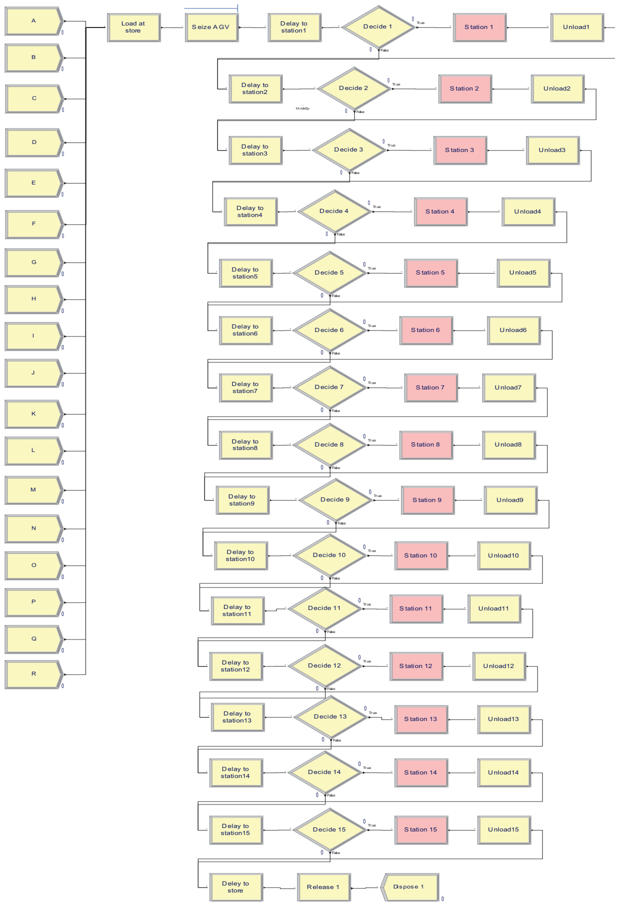

Fig. 2. The Schematic layout in the simulation program

TABLE 4
Distance between stations

| From-To | Distance (m) | Travel time (sec.) |
|---|---|---|
| Store to Station1 | 157.5 | 435.47 |
| Station1 to Station2 | 2.5 | 6.91 |
| Station2 to Station3 | - | - |
| Station3 to Station4 | 2.5 | 6.91 |
| Station4 to Station5 | 2.5 | 6.91 |
| Station5 to Station6 | 2.5 | 6.91 |
| Station6 to Station7 | 12.5 | 34.56 |
| Station7 to Station8 | 5 | 13.82 |
| Station8 to Station9 | 5 | 13.82 |
| Station10 to Station11 | 5 | 13.82 |
| Station11 to Station12 | 5 | 13.82 |
| Station12 to Station13 | - | - |
| Station13 to Station14 | 5 | 13.82 |
| Station14 to Station15 | 5 | 13.82 |
| Station15 to Store | 75 | 207.37 |

TABLE 5
The number of trips served by an AGV

| Station \ No. of AGV (Number of trips) | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|
| 1 | 5 | 5 | 5 | 5 | 5 |
| 2 | 38 | 41 | 43 | 43 | 43 |
| 3 | 13 | 15 | 15 | 15 | 15 |
| 4 | 54 | 58 | 61 | 61 | 61 |
| 5 | 2 | 2 | 2 | 2 | 2 |
| 6 | 3 | 4 | 4 | 4 | 4 |
| 7 | 16 | 18 | 18 | 18 | 18 |
| 8 | 9 | 9 | 9 | 9 | 9 |
| 9 | 1 | 1 | 2 | 2 | 2 |
| 10 | 9 | 12 | 12 | 12 | 12 |
| 11 | 21 | 28 | 28 | 28 | 28 |
| 12 | 2 | 2 | 2 | 2 | 2 |
| 13 | 18 | 21 | 22 | 22 | 22 |
| 14 | 4 | 5 | 5 | 5 | 5 |
| 15 | 15 | 18 | 18 | 18 | 18 |
| Total | 210 | 239 | 246 | 246 | 246 |

TABLE 6
The waiting time and utilization

| Number of AGV (unit) | Waiting Time (sec) | % Utilization |
|---|---|---|
| 8 | 3.44 | 87.76 |
| 9 | 1.62 | 78.01 |
| 10 | 0.96 | 70.21 |

## IV. DISCUSSION

This paper demonstrates simple quantitative and simulation approach to design an AGV in the production line. Both methods provide the same result. However, there is still some research issues needed to be addressed. One of the most interesting ones is the optimum AGV scheduling with traffic consideration. For example, with one way route any AGV at the beginning of the line can jam the rest of carrier.

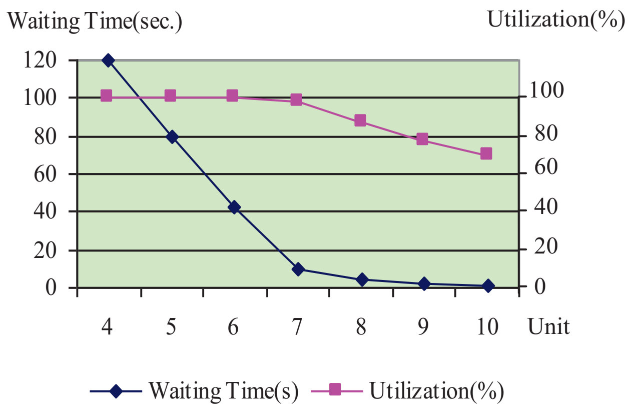


Fig. 3. The result of the simulation program

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