An Example of Determining the Number of Automatic Guided Vehicles

Grado Department of Industrial and Systems Engineering
Virginia Tech
102 Durham Hall (0118)
Blacksburg, VA 24061

Russell D. Meller
Amol Goel
Rohith Kori
agv@vt.edu

The information contained in this report is meant to serve as a simplified representative example and no general conclusions should be drawn from it. For any real-world project, both the data and the analysis are more extensive than illustrated here.

No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the express prior written permission of the Grado Department of Industrial and Systems Engineering at Virginia Tech and the Material Handling Industry of America.

©2004 Russell D. Meller and Virginia Tech
All Rights Reserved.
Printed in the United States of America

1.0 Introduction

Determining the number of automatic guided vehicles (AGVs) for a system can be a challenging endeavor. This report aims to de-mystify the process by presenting a simplified representative example. By going through the example, the user can understand what data are needed and what calculations are considered in determining the number of vehicles.

This report was requested by the AGV Product Section of the Material Handling Industry of America. To learn more about AGVs, visit the Material Handling Industry of America's AGV product section at http://www.mhia.org./psc/PSC_Products_GuidedVehicle.cfm.

2.0 Automatic Guided Vehicle System Design

The process of designing an automatic guided vehicle system is illustrated in Figure 1.

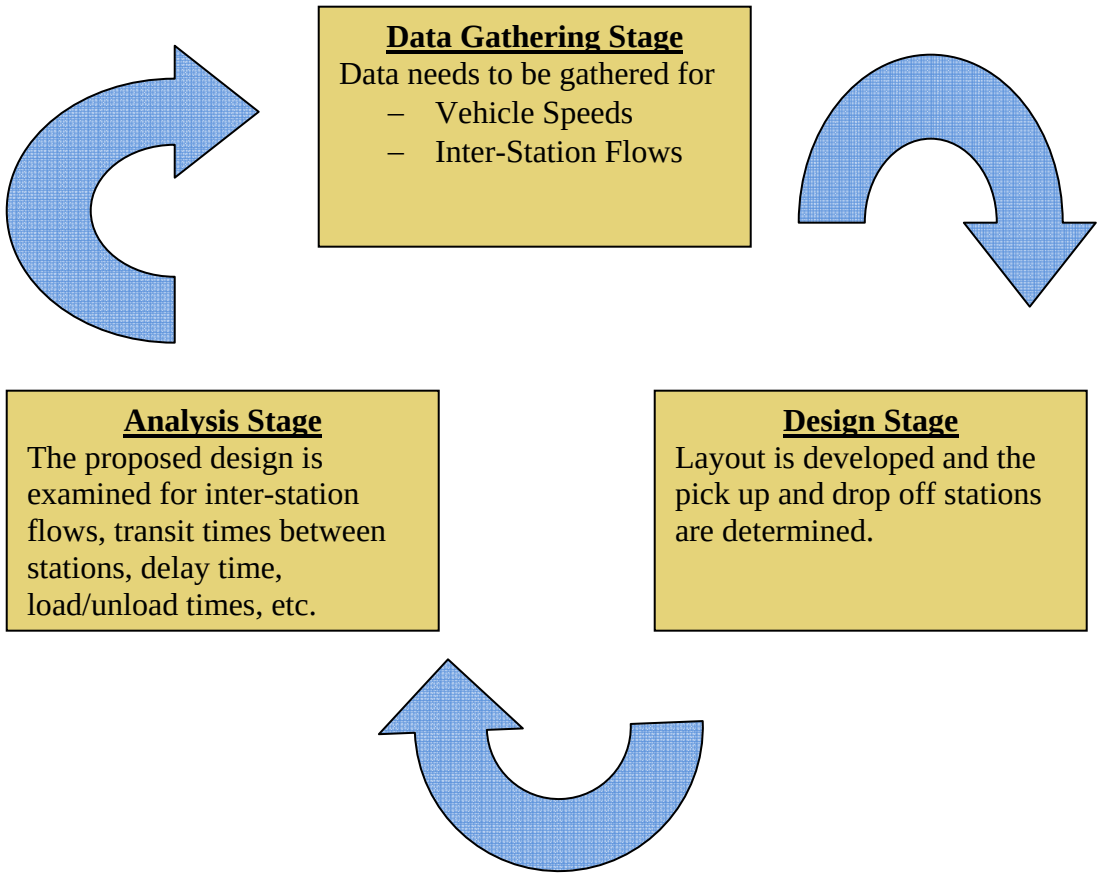

Figure 1: Iterative Process of Designing an Automated Guided Vehicle System.

The above three stages are iterative in nature and will be repeated several times before a final solution is determined. The result of this analysis will be vehicle requirements, the dispatching sequencing method, pickup/deposit point and storage space requirements.

For more information on automatic guided vehicle system design, the reader is referred to:

http://www.mhia.org/bs/BS_Other_Perspect_Classics_Documents.cfm?catid=55&keyid=1234

This report examines a decision made in the analysis phase: determining the number of AGVs.

3.0 Determining the Number of AGVs

3.1 Data Needed

3.1.1 Layout Definition

The starting point in determining the number of AGVs is a layout of the possible AGV system. This would include determining which stations will be served by AGVs, the appropriate pickup and deposit point for each station, and an approximate flow path for the AGVs. From the AGV system layout, the user can then specify or determine some of the critical data for such a project, including:

- The number of stations served by the AGVs.
- For each pickup point, the distance to each other station's deposit point in the system (to account for loaded AGV travel).
- For each deposit point, the distance to each other station's pickup point in the system (to account for unloaded AGV travel).

3.1.2 Material Flow

The next major piece of data that is needed relates to the material flow in the system. A good understanding of which loads will be handled by the AGVs is necessary to specify the workload on the system.

3.1.3 AGV Vehicle Specifications

The final major piece of data that is needed relates to the AGVs themselves. Data on vehicle speed (both loaded and unloaded), pickup/deposit times, maximum AGV utilization to plan for, how many minutes per hour the AGV will be available, and the assumed congestion factor of the system. These data are not always easy to specify going into a project, but an experienced AGV supplier can provide appropriate estimates based on your conceptual system. Later in the

design process, simulation studies are often used to help determine or verify this information and predict the impact on the AGV system performance.

3.2 Example

Here are the data that would be needed for a typical, rough-cut calculation on the number of AGVs in a system.

- Number of stations
- Loaded distance traveled between stations
- Unloaded distance traveled between stations
- Automated Guided Vehicle Parameters
- AGV System Parameters

For our example system, we will consider seven stations that are arranged such that the following matrices indicate the loaded distance traveled and unloaded distance traveled between pairs of stations.

Loaded distance is defined as the distance the AGV has to travel from the source station (pickup point) to the destination station (drop-off point) when it is transporting a load (P → D).

Loaded Travel Distance Data

Source	Destination 1	2	3	4	5	6	7
1	0.00	240.00	200.00	240.00	200.00	160.00	200.00
2	240.00	0.00	100.00	140.00	100.00	120.00	200.00
3	200.00	140.00	0.00	160.00	200.00	160.00	360.00
4	200.00	160.00	180.00	0.00	180.00	160.00	200.00
5	200.00	160.00	160.00	100.00	0.00	140.00	320.00
6	200.00	180.00	120.00	140.00	140.00	0.00	240.00
7	240.00	240.00	240.00	240.00	240.00	200.00	0.00

In the above example, the loaded travel distance from Station 1 to Station 2 is 240 distance units. Distances are typically measured in feet but can be defined in meters (or any other distance unit) as long as consistency is maintained throughout.

Unloaded distance is the distance traveled between departments when the vehicle is traveling empty from the drop-off point to a pickup point (D → P). In some AGV systems, the loaded and unloaded distances are different due to the flow path network. The units of loaded and unloaded distance are assumed to be the same.

Unloaded Travel Distance Data							
	Destination						
Source	1	2	3	4	5	6	7
1	0.00	360.00	200.00	240.00	200.00	160.00	200.00
2	240.00	0.00	100.00	140.00	100.00	120.00	200.00
3	200.00	140.00	0.00	160.00	200.00	160.00	360.00
4	200.00	160.00	180.00	0.00	180.00	160.00	200.00
5	200.00	160.00	160.00	100.00	0.00	140.00	320.00
6	200.00	180.00	120.00	140.00	140.00	0.00	240.00
7	240.00	240.00	240.00	240.00	240.00	200.00	0.00

In the above example, the unloaded travel distance from station 1 to station 2 is 360 distance units.

The next major piece of data concerns the flow data. For our example, we will assume that the flow must be satisfied over a two-shift (i.e., 16 hour) operation.

Flow Data							
	Destination						
Source	1	2	3	4	5	6	7
1	0.00	40.00	20.00	30.00	50.00	20.00	24.00
2	40.00	0.00	28.00	40.00	10.00	28.00	40.00
3	30.00	50.00	0.00	40.00	42.00	62.00	40.00
4	40.00	50.00	60.00	0.00	50.00	40.00	60.00
5	40.00	60.00	40.00	40.00	0.00	30.00	30.00
6	40.00	60.00	50.00	50.00	36.00	0.00	40.00
7	10.00	60.00	40.00	50.00	20.00	30.00	0.00

In the above example, 40 trips are needed to be completed by the AGVs between station 1 and 2 in 16 hours.

The final major piece of data relates to the AGVs and the AGV system parameters. For this example, we will assume that our AGVs travel at a speed of 250 feet per minute (vehicle speeds in the industry currently range from 150 fpm to 300 fpm).

Like most pieces of support equipment in a facility, AGVs cannot be utilized at their full capacity without a corresponding negative impact on service times. That is, typically, when designing an AGV system, an AGV utilization of less then 100% is assumed to avoid excessive waiting time on the AGV. A utilization of 80-90% is normally used. We will use 85% in our example.

The pickup and the deposit times of each vehicle for each load are assumed to be 6 seconds in our example.

Vehicle availability is influenced by factors like time for battery swapping or charging. Typical battery swapping time ranges from 3 - 6 minutes. In the case of automatic battery charging, a good rule of thumb is to plan a 1:1 relationship between actual running time and required charging time. A 3-hour running time for the AGV would mean a 3 hour charging time. On an hourly basis the AGV would now be available for 30 minutes for actual usage. In our example we will assume that the vehicles are available for 55 minutes out of every hour.

Most AGV systems with multiple vehicles will have some unavoidable vehicle congestion delays. A vehicle congestion delay factor represents the percentage by which loaded and unloaded vehicle travel times are increased due to congestion in the travel path. Vehicle congestion delay factors are dependent on the layout of the facility as well as that of the travel paths. Well-designed layouts will have congestion delay factors close to zero. In our example we will assume a more conservative vehicle congestion delay factor of 10%.

Most AGVs travel at a slower speed when loaded than when unloaded. A loaded/unloaded travel delay factor is the percentage by which the vehicle speed is reduced when it is loaded. This reduction will partly depend on the nature of the load; e.g., its stability or fragility. In our example we will assume a loaded/unloaded travel delay factor of 5%.

For the above data, two models, one model for a minimum number of AGVs and one model for an expected number of AGV can be used. The models are based on rough-cut models developed and tested by both academics and AGV vendors. Both models calculate the amount of time needed for loaded travel exactly using flow times distance divided by AGV speed. Unloaded travel time uses the same type of equation, but different estimates for the time needed for unloaded travel are used in each model. The total amount of pickup and deposit times are then added to the travel times. The time the vehicle is available and congestion delay factors are then used to establish the appropriate number of vehicles without exceeding the vehicle utilization constraint.

For the models we used, we compute the minimum number of vehicles to be 3 and the expected number of vehicles to be 4. This means that the actual system may be able to meet throughput with 3 AGVs, but we expect that 4 AGVs would be needed. Before any system is commissioned, a detailed simulation study needs to be performed to determine a better estimate of the number of vehicles as well as to verify other system parameters. However, the preliminary analysis provides a good starting point for the simulation development.

4.0 Summary

Determining the number of AGVs in a system is more complex than what was presented here, but our goal was to expose those not familiar with AGV system design to some of the aspects of such an undertaking. In particular, by highlighting the kind of data used in the calculation, the user will now be aware of what things to prepare in advance and what questions an AGV supplier is likely to ask.