Automatic Guided Vehicles Decision-Support Tool

Training Manual

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1.0 Introduction

The Automatic Guided Vehicles-Decision Support Tool (AGV-DST) is a decision support tool to help users decide on the number of Automatic Guided Vehicles to be deployed in a facility.

This document is intended for the first time user. Since AGV-DST is a design tool, it is assumed that the user is familiar with the terms and terminologies related to AGVs.

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

The manual also assumes that the user has Microsoft Excel and the Solver Add-in installed on the computer where this tool is being run. For instructions on installing Microsoft Excel and Solver Add-in, refer to Microsoft Office documentation. It is also assumed that the user is comfortable with the use of Excel.

2.0 Automatic Guided Vehicle System Design

The process of designing an automatic guided vehicle system is an iterative one and can be divided into three stages:

1. **Data Gathering**
   Data need to be gathered for
   a. Vehicle Speeds.
   b. Inter-Station Flows.
2. **Design Stage**
   The layout is developed and the pick up and drop off stations are determined.
3. **Analysis Phase**
   The proposed design is examined for inter-station flows, transit times between stations, delay time, load/unload times, etc.

The above three steps 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, dispatching sequence 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

AGV-DST is intended to be used in the analysis phase. It is assumed that the data gathering stage and the design stage have been completed and all data are available.

3.0 Installation

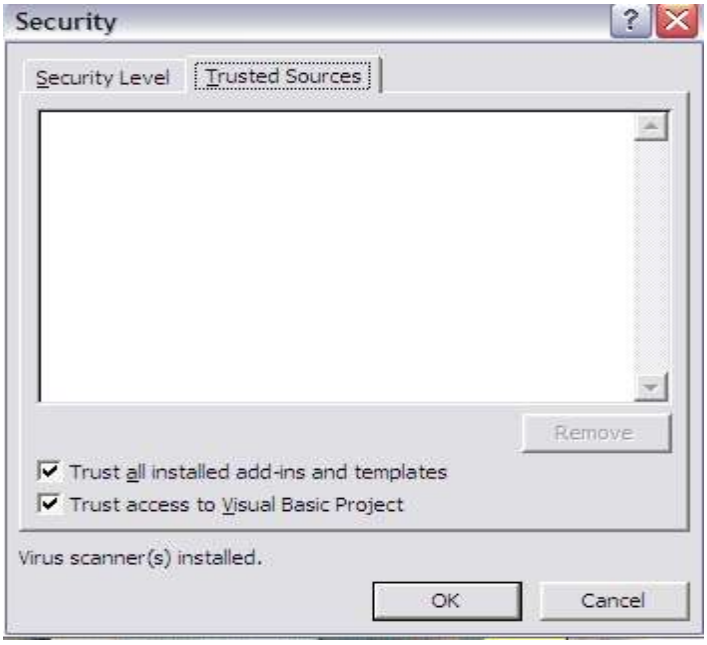
AGV-DST is developed using Visual Basic for Applications (VBA) and Excel. It is assumed that Excel has been installed on the user machine. It is also assumed that the Standard Solver Add-in has been installed during the installation of Excel.

Open the AGVDST Excel file

Enable Macro

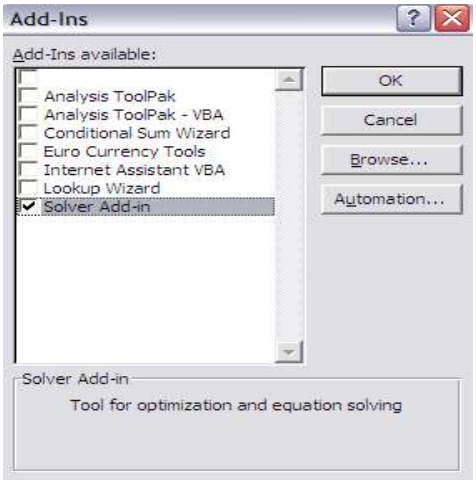
Click on Tools --> Macro --> Security and enable the medium security level macro option as shown below. (This step is needed if your security setting is currently set to High.)

Click on Tools → Macro → Security →Trusted Sources Tab → Check the box titled “Trust access to Visual Basic Project” and the box titled “Trust all installed add-ins and templates.” Click Ok.



Install Solver Add-in

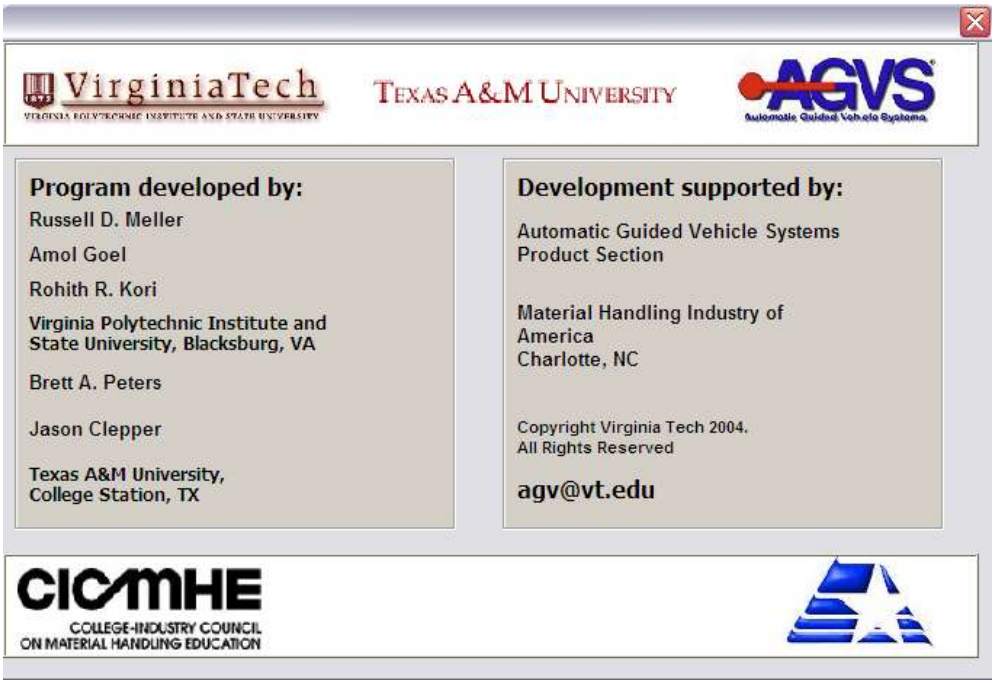
Click on Tools → Add-Ins. Check the Solver Add-in check box. If the Solver Add-in is already checked, uncheck it and click OK. Now again click on Tools → Add-Ins and check the Solver Add-in check box.



Now the user is ready to use the software tool.

4.0 USING THE SOFTWARE

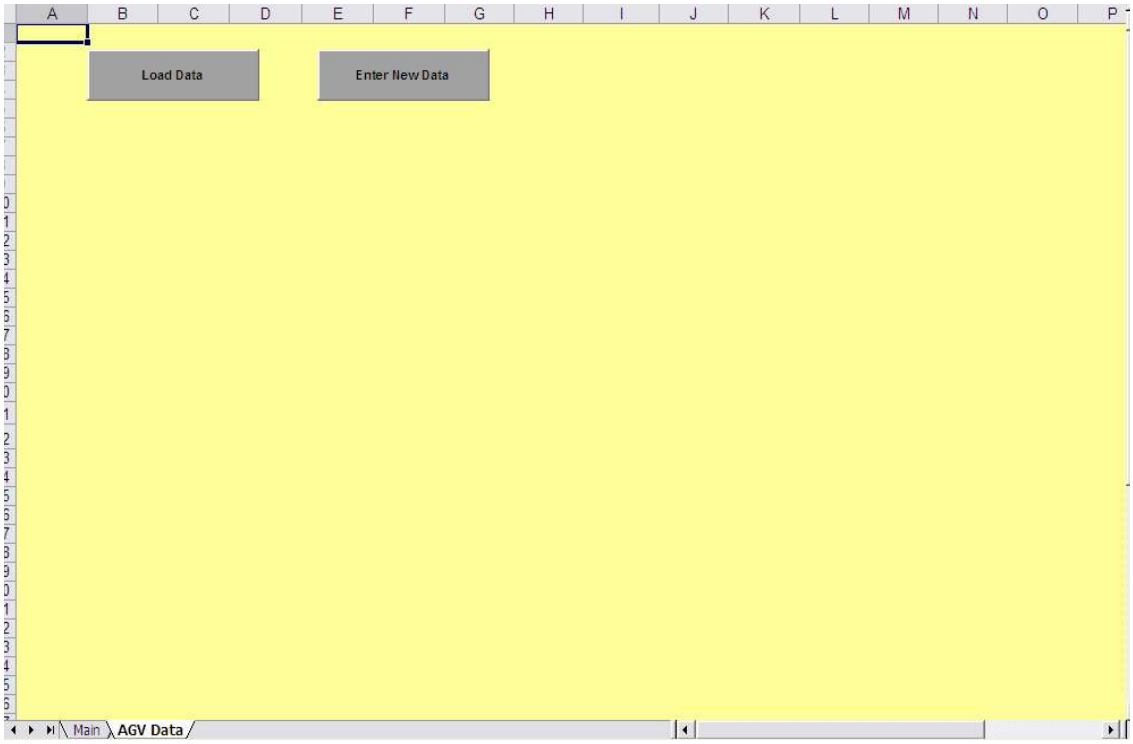
On opening the file AGVDST.XLS in Excel, the splash screen is displayed first, followed by the main screen.



Splash Screen

Main Screen

After clicking Next on the Main worksheet, the user is taken to the AGV Data worksheet.

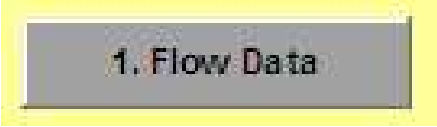


Clicking on the “Enter New Data button” enables the user to enter data for a new problem to be solved. Clicking on “Load Data button”, loads data and results of a previously stored problem.

Click Enter New Data Button

Select the Number of stations from the drop down list.

Click 1. Flow Data Button



Enter Flow Data

Enter Flow Data in the Table Below (# Trips / Time Unit) and Define Time Unit

From \ To	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

Enter inter-station flows in the table as shown above. The flow value must be a positive real value. The unit of flow, for entries in table is *number of trips per time unit*. In the above example, 40 trips are needed to be completed by the AGVs between station 1 and 2 in 16 hours (time unit defined next).

Define Time Unit

Enter Time Unit (Hours) | 16 | Type in a Value or Select From List

Select Time unit from the list or type in your own value. The *time unit is defined in hours*. The time unit in the above example is 16 hours; i.e., 40 trips are needed between station 1 and 2 every 16 hours.

Click 2. Loaded Distance Button

2. Loaded Distance

Enter Loaded Distance Data

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).

Enter Loaded Travel Distances in the Table Below (P -> D)

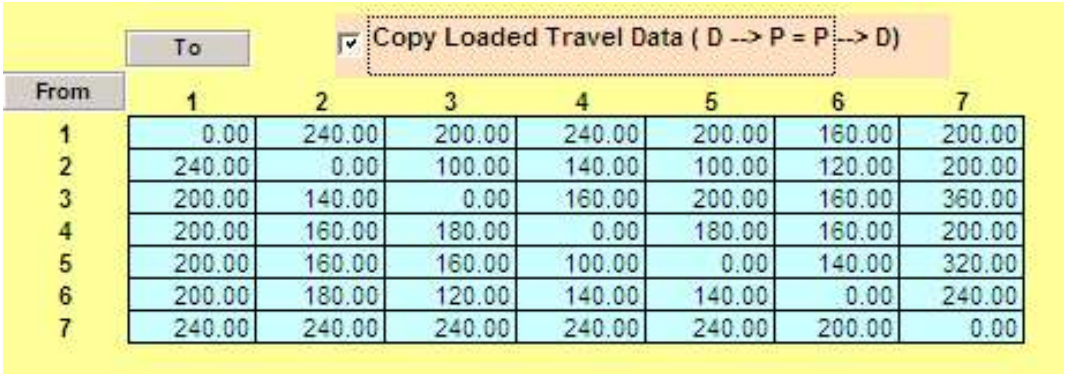
From \ To	1	2	3	4	5	6	7
1	0.00	240.00	200.00	240.00	200.00	160.00	200.00
2	240.00	0.00	100.00	140.00	100.00	120.00	200.00
3	200.00	140.00	0.00	160.00	200.00	160.00	360.00
4	200.00	160.00	180.00	0.00	180.00	160.00	200.00
5	200.00	160.00	160.00	100.00	0.00	140.00	320.00
6	200.00	180.00	120.00	140.00	140.00	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 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.

Click 3. Unloaded Distance Button

Enter Unloaded Distance Data

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).
If both the Loaded and Unloaded distance from one station to the next is the same, check the box to Copy Loaded Distance Data in the unloaded distance table (D → P = P → D). The entries that are different between the two tables can be edited later. The units of loaded and unloaded distance are assumed to be the same.



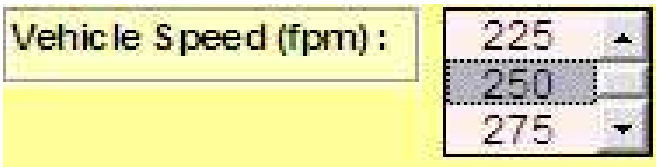
From \ To	1	2	3	4	5	6	7
1	0.00	240.00	200.00	240.00	200.00	160.00	200.00
2	240.00	0.00	100.00	140.00	100.00	120.00	200.00
3	200.00	140.00	0.00	160.00	200.00	160.00	360.00
4	200.00	160.00	180.00	0.00	180.00	160.00	200.00
5	200.00	160.00	160.00	100.00	0.00	140.00	320.00
6	200.00	180.00	120.00	140.00	140.00	0.00	240.00
7	240.00	240.00	240.00	240.00	240.00	200.00	0.00

In the above example, the unloaded travel distance from station 1 to station 2 is 240 units.

Click 4. Vehicle Data Button

Enter Vehicle Speed

Select the vehicle speed in *feet per min* from the list.



In the above example, the vehicle speed of 250 fpm is selected. Vehicle speeds in the industry currently range from 150 fpm to 300 fpm.

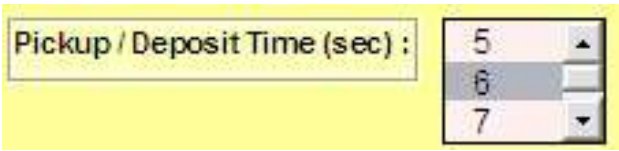
Enter Maximum Vehicle Utilization

Enter the maximum utilization of the AGV vehicle permissible in the system.

Vehicle utilization is the designed utilization of the vehicle. 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.

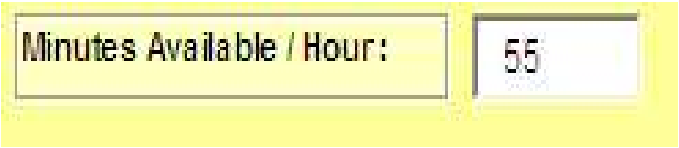
Enter Pickup/Deposit Time

Enter the *pickup/deposit time* in seconds for each vehicle. The pickup and the deposit time of each vehicle for each load are assumed to be the same. In the case that this is not true, enter the weighted average of the pickup/deposit time.



Enter Vehicle Availability per Hour

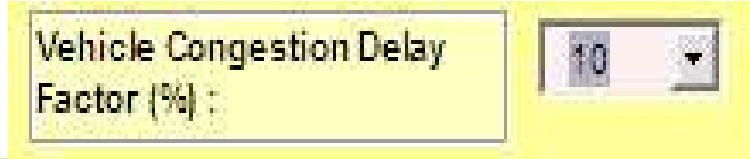
Enter the time the vehicle is available for actual use in *minutes available per hour*. Vehicle availability is influenced by factors like time for battery swapping or charging.



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.

Enter Vehicle Congestion Delay Factor

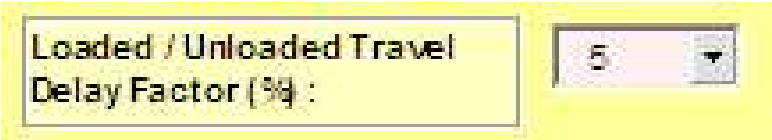
Enter the vehicle congestion delay factor as a percentage. The vehicle congestion delay factor represents the percentage by which loaded and unloaded vehicle travel times are increased due to congestion in the travel path. If no such delay exists in the system, enter the vehicle congestion delay factor as zero.



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.

Enter the Loaded/Unloaded Travel Delay Factor

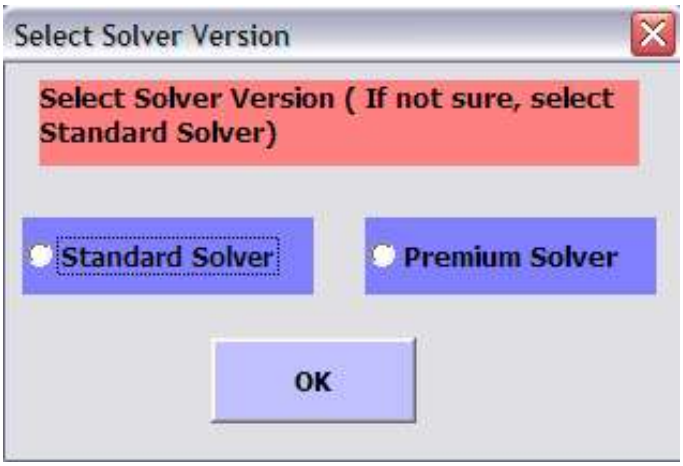
Enter the loaded/unloaded travel delay factor as a percentage. The loaded/unloaded travel delay factor is the percentage by which the vehicle speed is reduced when it is loaded. If loaded and unloaded vehicle speeds are same, enter the loaded/unloaded travel delay factor as zero.



Click 5. Calculate Results

Select Solver Version Installed

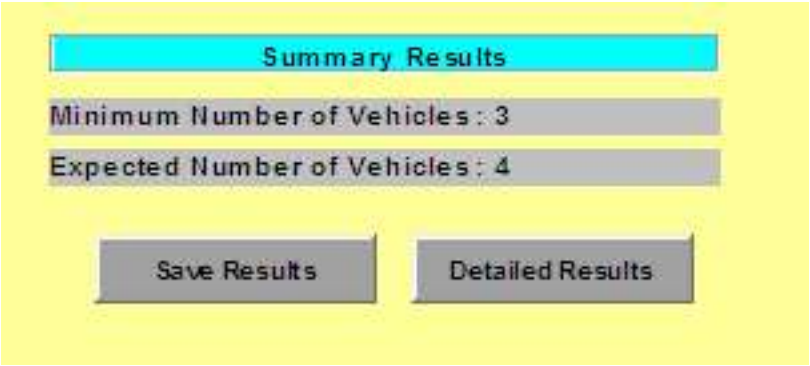
Define the solver version installed on your computer. By default, Standard Solver is installed along with Microsoft Excel. Unless you have purchased Premium Solver, select Standard Solver*.



* For limitations of Standard Solver for this application – see Section titled Limitations of Standard Solver (Section 5.0).

View and Save Results

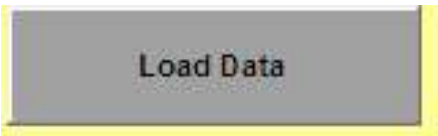
The minimum number and expected number of vehicles required to satisfy the inter-station flows defined in the problem is shown.



Clicking on the Save Results button saves the currently active data and the results. This action overwrites previously saved data. If previously stored data is required, it is suggested that the user save the whole file under a separate name.

Load Data Button

Clicking on the Load Data Button displays the previously saved problem data and results.



Detailed Results

DETAILED RESULTS FOR AGV CALCULATION

Back to AGV Data Sheet

Minimum Number of Vehicles : 3

Maximum Number of Vehicles : 4

Number of Stations : 7

Number of Hours per Time Unit : 16

	100 % Utilization	85% Utilization
Time Per Vehicle (mins) :	880	748

Minimum Number of Vehicles Calculation (Maxwell Muckstadt Model)

Material Handling Time : 332

Total Travel Time : 1889.296

	Without Delay Factors	With Loaded / Unloaded Travel Factor	With Congestion Delay Factor also considered
Loaded Travel Time	1247.68	1386.311	1459.275
Unloaded Travel Time	93.12	N A	98.021

Unloaded Travel Time Matrix

	1	2	3	4	5	6	7
1	0	0	0	0	0	10.24	0
2	0	0	10.4	28	12.8	12.48	0
3	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
7	0	0	0	0	0	19.2	0

Loaded Travel Time Matrix

	1	2	3	4	5	6	7
1	0.00	38.40	16.00	28.80	40.00	12.80	19.20
2	38.40	0.00	11.20	22.40	4.00	13.44	32.00
3	24.00	28.00	0.00	25.60	33.60	39.68	57.60
4	32.00	32.00	43.20	0.00	36.00	25.60	48.00
5	32.00	36.00	24.00	16.00	0.00	16.80	38.40
6	32.00	43.20	24.00	28.00	20.16	0.00	38.40
7	9.60	57.60	38.40	48.00	19.20	24.00	0.00

Expected Number of Vehicles Calculation (Egbelu Model)

Material Handling Time : 332

Total Travel Time : 2887.771

	Without Delay Factors	With Loaded / Unloaded Delay Factor	With Congestion Delay Factor also considered
Loaded Travel Time	1247.68	1386.311	1459.275
Unloaded Travel Time	1041.672	N A	1096.497

Expected Number of Unloaded Trips Matrix

	1	2	3	4	5	6	7
1	22.17	22.41	31.81	36.14	28.92	33.25	25.30
2	35.47	35.86	50.89	57.83	46.27	53.20	40.48
3	26.38	26.67	37.85	43.01	34.41	39.57	30.11
4	27.71	28.01	39.76	45.18	36.14	41.57	31.63
5	23.06	23.31	33.08	37.59	30.07	34.58	26.31
6	23.28	23.53	33.40	37.95	30.36	34.92	26.57
7	25.94	26.22	37.21	42.29	33.83	38.91	29.60

Unloaded Travel Time Matrix

	1	2	3	4	5	6	7
1	0.00	21.51	25.45	34.70	23.13	21.28	20.24
2	34.05	0.00	20.36	32.39	18.51	25.54	32.39
3	21.10	14.93	0.00	27.53	27.53	25.33	43.36
4	22.17	17.93	28.63	0.00	26.02	26.60	25.30
5	18.44	13.98	19.85	15.04	0.00	19.37	33.68
6	18.62	16.94	16.03	21.25	17.00	0.00	25.50
7	24.90	25.17	35.73	40.60	32.48	31.12	0.00

Loaded Travel Time Matrix

	1	2	3	4	5	6	7
1	0.00	38.40	16.00	28.80	40.00	12.80	19.20
2	38.40	0.00	11.20	22.40	4.00	13.44	32.00
3	24.00	28.00	0.00	25.60	33.60	39.68	57.60
4	32.00	32.00	43.20	0.00	36.00	25.60	48.00
5	32.00	36.00	24.00	16.00	0.00	16.80	38.40
6	32.00	43.20	24.00	28.00	20.16	0.00	38.40
7	9.60	57.60	38.40	48.00	19.20	24.00	0.00

Vehicle Data

Vehicle Speed(fpm) : 250

Minutes Available / Hour : 55

Vehicle Congestion Delay Factor(%) : 5

Max Vehicle Utilization(%) : 85

Pickup/Deposit Time(sec) : 6

Loaded / Unloaded Travel Delay Factor(%) :10

Flow Data Matrix

	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

Unloaded Distance Matrix

	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	150.00	150.00	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

Loaded Distance Matrix

	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	150.00	150.00	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

Clicking on the Detailed Results shows the intermediate results obtained along with the summary results.

5.0 Limitations of Standard Solver

Selecting Standard Solver limits the accurate calculation of the minimum number of vehicles to cases with less than or equal to 14 stations. When the number of stations exceeds 14, an approximate method is used to calculate the minimum number of vehicles.

In certain cases, the approximate method used may lead to inconsistent results. In such cases, the minimum number of vehicles is not displayed.

If there is a need to calculate the minimum number of vehicles for more then 14 stations consistently, it is strongly recommended that the user install Premium Solver Add-in for Excel available from Frontline Systems, Inc. (http://www.solver.com).

6.0 Critical Error and Warning Messages

Given below is an explanation of critical error and warning messages as well as the steps to be taken to avoid them.

Solver Not Found - Abort Calculation of Minimum Number of Vehicles.

The error is generated when Solver has not been installed. Please make sure that Solver Add-in is installed. This is done by running Excel setup. Solver has to be installed in its default path. For help on installing Solver for Excel, please refer to the Microsoft Excel documentation.

Microsoft VB Project Privileges not found.

Goto Tools ---> Macros ---> Security option.
Click on Trusted Sources tab. Check both the boxes titled Trust Access to Visual Basic Project and Trust all Installed Add-ins and templates. For more instructions on how to do this, refer to the installation section of this manual.

Premium Solver needs to be installed to solve this problem.

The approximation used to calculate the minimum number of vehicles is not consistent with the problem data. Install Premium Solver if you need minimum number of vehicles for this problem data. For more information, refer to the Limitations of Standard Solver section of this manual.

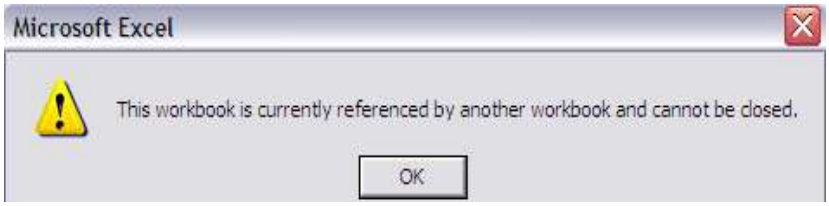
Solver: An unexpected internal error, occurred, or available memory was exhausted.

The easiest way to avoid this error is to follow the installation instruction outlined in this manual. Otherwise, please proceed as detailed below.

This message indicates that the Solver Add-in has not been properly referenced.

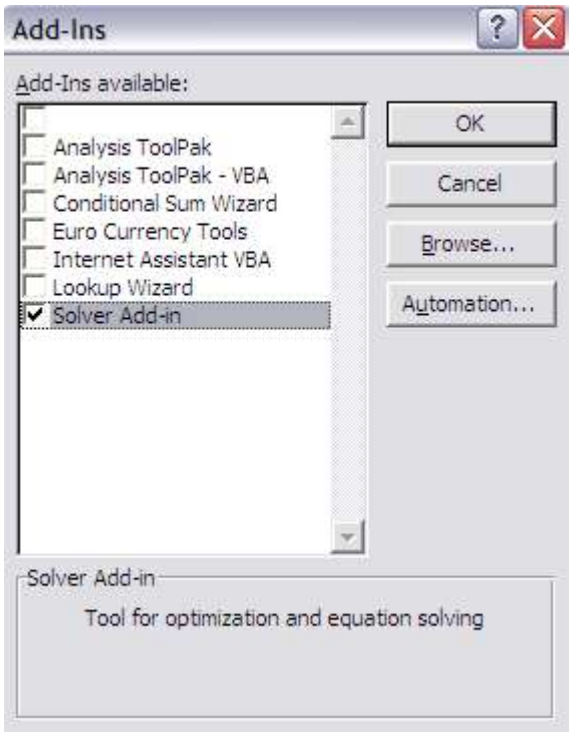
To correct this click on Tools ---> Add-ins. Uncheck the Solver Add-in check box (Uncheck the box even if it has been checked). Click Ok.

You may get a warning message like the one given below:

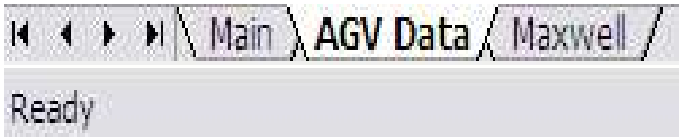


Click Ok.

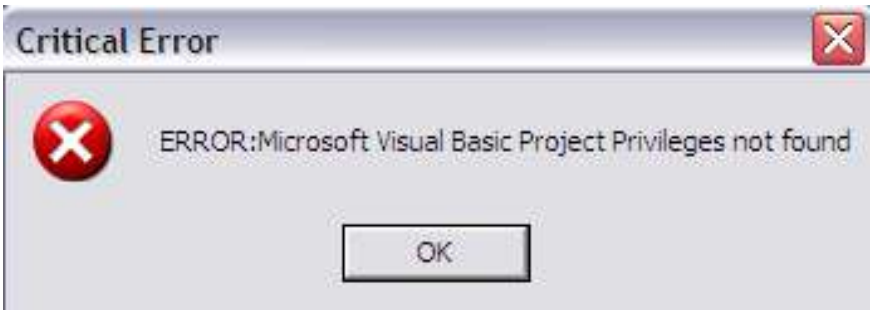
Now Click on Tools --> Add -Ins. Check the Solver Add-in check box. Click Ok.



Now click on AGV Data Sheet tab and click on results again.



Microsoft Visual Basic Project Privileges not found or Error in Hidden Module 11



Goto Tools-->Macros-->Security option.
Click on Trusted Sources Tab.
Uncheck Trust Access to Visual Basic Project.
Recheck Trust Access to Visual Basic Project.
Check Trust all Installed Add-ins and Templates.
Click OK.

Warning Message

Approximation Used in Calculating the Minimum Number of Vehicles

This message is shown when the user is calculating the number of vehicles required with more then 14 stations and only the standard version of Solver is installed.*

* For more details, refer to the section on Limitations of Standard Solver (Section 5.0).

7.0 Appendix A: Glossary of Terms

Battery Charging:

See Vehicle Availability.

Flow Data:

Flow data defines the number of trips made by an AGV between different stations (departments/assembly points). In a unit load AGV this is the number of unit loads moved between various departments during one time unit.
See also Time Unit.

Loaded Distance:

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). For example, if the AGV is transporting a load from station 1 to station 2, the loaded distance is the distance between pickup point of station 1 and the deposit point of station 2. Distances are typically measured in feet but can be defined in meters (or any other distance unit) as long as consistency is maintained throughout.
See also Unloaded Distance.

Loaded / Unloaded Travel Delay Factor:

The loaded/unloaded travel delay factor is the percentage by which the vehicle speed is reduced when it is loaded. In some applications, the AGV travels slower when it is loaded versus when it is unloaded. In the case that no such speed differential exists, the loaded/unloaded travel delay factor is zero.

Material Handling Time:

Material handling time is the total time required for pickup and deposit of all loads in seconds. Material handling time is given by:

Material Handling Time = Pickup/Deposit time x Total number of loads moved x 2

Maximum Vehicle Utilization:

See Vehicle Utilization.

Minutes Available per Hour:

Vehicle availability is the amount of time the vehicle is available for actual load transportation. Vehicle availability is influenced by factors like time for battery

swapping or charging. Typical battery swapping time range from 3 - 6 minutes. In case of automatic battery charging, a good rule of thumb is to plan 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.

Pickup and Deposit Time:

Pickup and deposit time is the time required for the vehicle to pickup and deposit the load at pickup and drop points. The pickup and deposit times of each vehicle is assumed to be the same. In case this is not true, a weighted average of the pickup/deposit times can be used. Pickup and deposit times depend on the kind of AGV system being used. Typical pickup and deposit times are in the range of 10 – 40 seconds based on the type of load being handled.

Time Unit:

The *time unit is defined in hours*. The flow entered in the flow data section is assumed to occur per time unit. Typical time units are 8 hours (one shift), 16 hours (two shifts) or 24 hours (one day).

Total Travel Time:

Total Travel time is the total time of vehicle movement required to fulfill the flow requirements under given vehicle characteristics. Total travel time is given by:

Total Travel Time = Loaded Travel Time + Unloaded Travel Time + Material Handling Time

Unloaded Distance:

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). When an empty vehicle is coming from station 2 to pickup a load at station 1 after dropping off a load at station 1, the unloaded distance is the distance traveled between the deposit point of station 2 and the pickup point of station 1. In many instances, the loaded and unloaded distances will remain the same. Distances are typically measured in feet but can be defined in meters (or any other distance unit) as long as consistency is maintained throughout.

Vehicle Speed:

Vehicle speed is the speed at which the AGV will move inside the facility. The vehicle speed is defined as feet per minute the vehicle travels. Typical vehicle speed values range from 150 fpm to 300 fpm.

Vehicle Congestion Delay Factor:

The 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.

Vehicle Utilization:

Vehicle utilization is the designed utilization of the vehicle. 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.