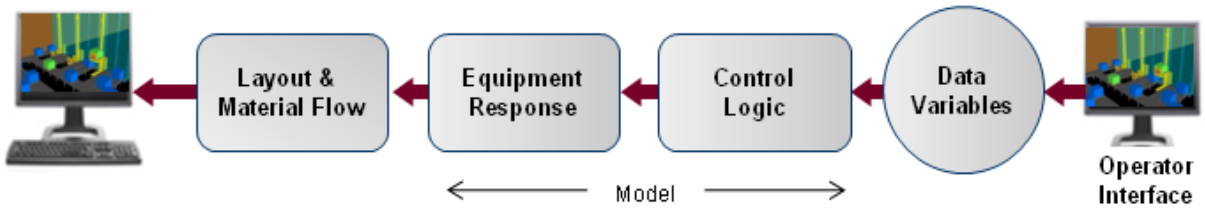
Continuous Improvement Using Simulation Model & Graphical User Interface

Scope of Work

The work described in this paper included developing a computer simulation model and graphical user interface (GUI) of the material handling system (AGV and ASRS), verifying the model, conducting experiments, documenting the completed simulation analysis, and then providing a tool for the customer to run experiments on their own.

Model Development Process

HK Systems (HKS) follows a structured approach to simulation model development and verification that ensures the model is a valid representation of the system and includes an appropriate level of detail both in statistical accuracy and in animation for debugging, validating and presenting model results. The model was initially written in the AutoMod 9.1 simulation language, but has since been upgraded to version 12.1.



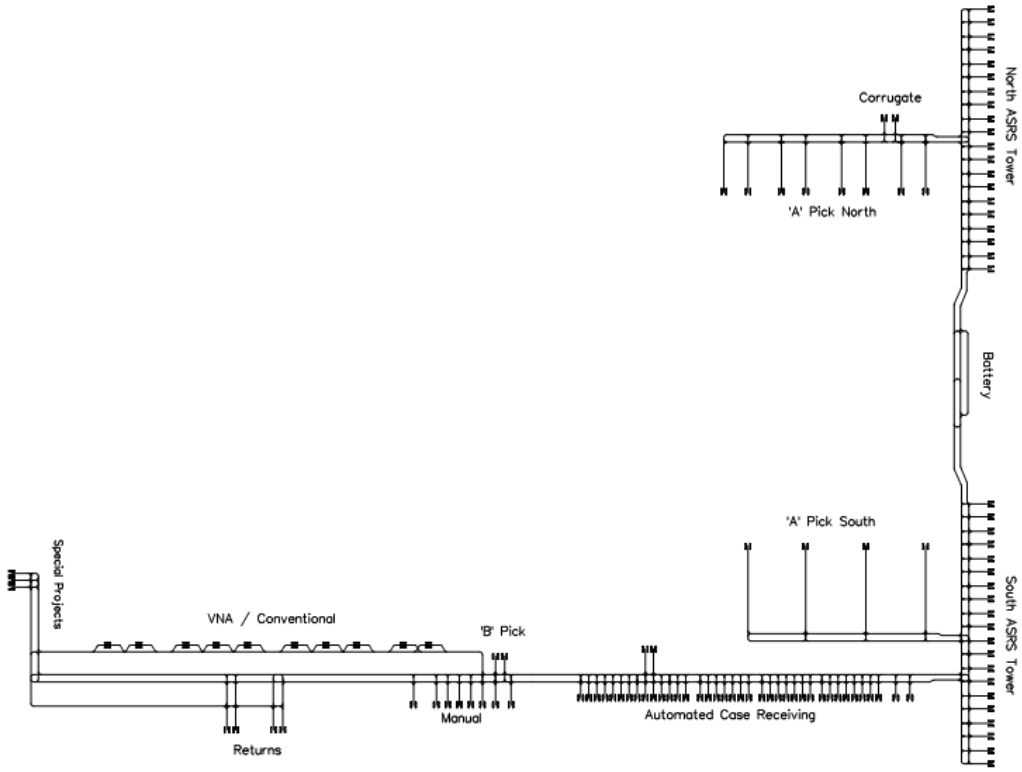
Simulation Process with User Interface

Simulation Objectives

The initial purpose of the simulation analysis was to determine the quantity of AGVs required to meet the customer's throughput requirements. This initial analysis was completed in 1998. Over the last 11 years, the model and GUI have been modified several times to reflect changes in the client's business practices and business model and to gain a better understanding of how to operate their distribution warehouse.

System Overview

The purpose of the AGV system is to move pallets of product from production to various locations to be stored and then when required to move those pallets from storage to shipping or back to other production areas. The AGV path layout is show below along with a brief description of each area:



AGV Path Layout

ASRS Towers - Product comes from the ACR areas and is stored into one of the aisles. Loads coming out of the ASRS Towers will be delivered to the various areas based on the percentage of pallets that go to each area.

Automated Case Receiving (ACR) - The model allows loads onto thirty of the thirty-five ACR pickup stands at a time. If there are loads waiting to move onto a stand, and there are already thirty in use, the load will wait for one load to be picked up by an AGV. Stands are selected at random, and then checked to see if there is already a load present. If there is, another stand is selected. Loads leaving the ACR area go to one of the ASRS Towers or to the VNA area. The destination is selected using a uniform distribution.

Manual Stands - The model generates loads from the manual stands using a uniform distribution. The stands are selected at random for the loads. The loads are given a destination based on the percentage of loads going to each area.

Returns - The model generates loads from the return stands using a uniform distribution. If the return stand is available then the load moves onto the stand and waits for an AGV to pick up the load.

Special Projects - The special projects stands are both input and output stands. If an AGV is delivering a load to the special projects area, it will come to a control point and check to see if a stand is available. If a stand is available, it will deliver the load to the stand. If there isn't a stand available, it will wait for twenty seconds and check again. If there still isn't a stand available, then the AGV will loop to allow empty AGVs into the area to pick up loads moving back to the ASRS Towers.

A Pick - All picks coming to the 'A' Pick area originate from the ASRS towers. 'A' Pick pallets in the north area enter 100% from the north stands for 'A' Pick. 'A' Pick pallets in the south area enter 67% from the south and 33% from the north to 'A' Pick. The model generates loads going to and from the 'A' pick area using a uniform distribution. The stands are selected at random for the loads. The loads are given a destination based on the percentage of loads going to each area.

B Pick - The model generates loads for the 'B' pick area using a uniform distribution. Loads being removed from the area are given a destination based on the percentage of loads going to each area. All loads coming to the 'B' Pick area come from the ASRS.

VNA\Conventional\Corrugate - The model generates loads for the VNA area using uniform distribution. Loads being delivered come from one of three areas: ACR, Manual or Returns. Loads being removed from the area are given a destination based on the percentage of loads going to each area. The loads leaving are empty pallet stacks; they are delivered to one of four areas: ASRS, ACR, Manual or Returns.

Battery Changing **-** At the initialization of the simulation model, each AGV is assigned a random battery runtime of zero to eight hours, indicating that the AGV will need to have its batteries changed after the runtime expires. The time is based on an eight-hour runtime per set of batteries. After the runtime expires, the AGV will not accept any more work but will instead travel to the battery area. In the battery area there are seven locations to facilitate battery changing. When the AGV arrives in the area it will travel to the location that is the furthest upstream to allow as many vehicles as possible into the area. If all seven locations are in use, the vehicle will wait for thirty seconds and check to see if there is an available location. If there still isn't a location available, the vehicle will loop on the path to allow other AGVs to pass. Once an AGV arrives at one of the seven battery changing locations it will wait for fifteen minutes for the batteries to be changed. After fifteen minutes the AGV returns to the system and is eligible for work assignments.

Summary of Results

The initial results focused on the quantity of AGVs required under different scenarios. The simulation results indicate that without any modifications to the AGV path, 37 AGVs will be required to meet the peak throughput rates. By adding a new path west of the 'A' pick area, with a travel direction going from north to south, the throughput rates could be achieved with 35 AGVs.

Throughput Results

	Moves per Hour										
Number of AGVs	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
Throughput Target	325	325	325	325	325	325	325	325	325	325	325
Original Path	283	290	294	301	308	314	319	324	**329**	330	330
South to North Path	285	289	298	303	309	316	322	**327**	330	330	330
North to South Path	295	302	308	315	321	**328**	330	330	330	330	330

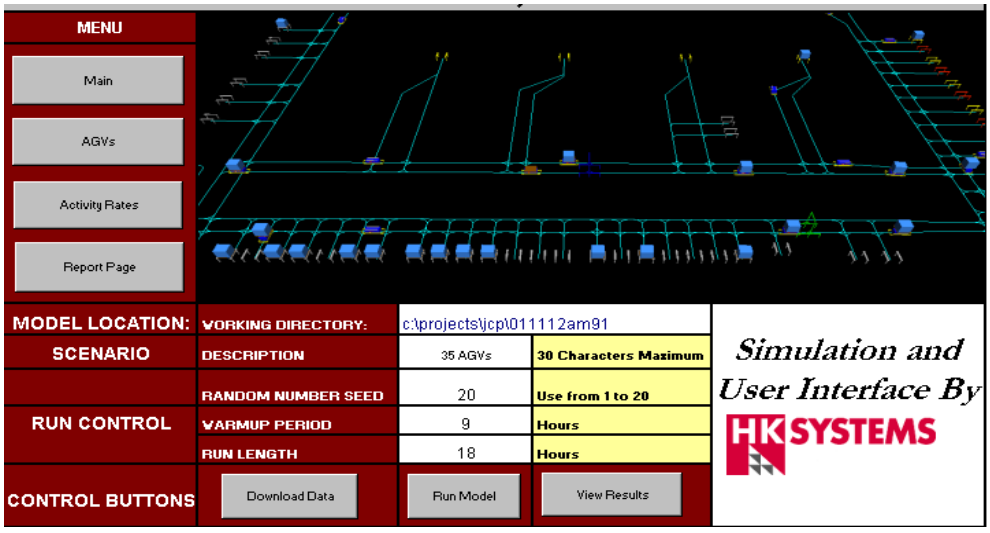
The simulation shows a very high utilization for the AGVs. HKS recommends a utilization of not more than 85%. As is shown in the table below, the only utilization percentage that is less than 90% is the system configuration with the north to south path near the 'A' pick area and using 40 vehicles.

AGV Utilization Results

AGV Percent Utilized											
Number of AGVs	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
Target < 85%	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0
Original Path	92.0	91.4	91.7	92.2	92.2	91.8	92.4	91.9	92.0	92.5	92.0
South to North Path	92.2	92.2	92.5	92.0	92.0	92.3	92.5	92.4	92.6	92.3	91.8
North to South Path	92.2	92.1	92.4	92.5	92.2	92.4	92.7	92.0	90.7	90.0	**88.8**

The second part of this effort was to make a GUI that allows the customer to test various production and operating scenarios on their own. The following details the input sheets of the GUI and the output report that is generated.

The *Main sheet* contains the simulation run time information such as the working directory, scenario name, random seed set, warm-up length and run length. The Main sheet also contains control buttons for downloading the spreadsheet data to the simulation input files. There are also buttons for running the simulation model and reviewing the model reports.



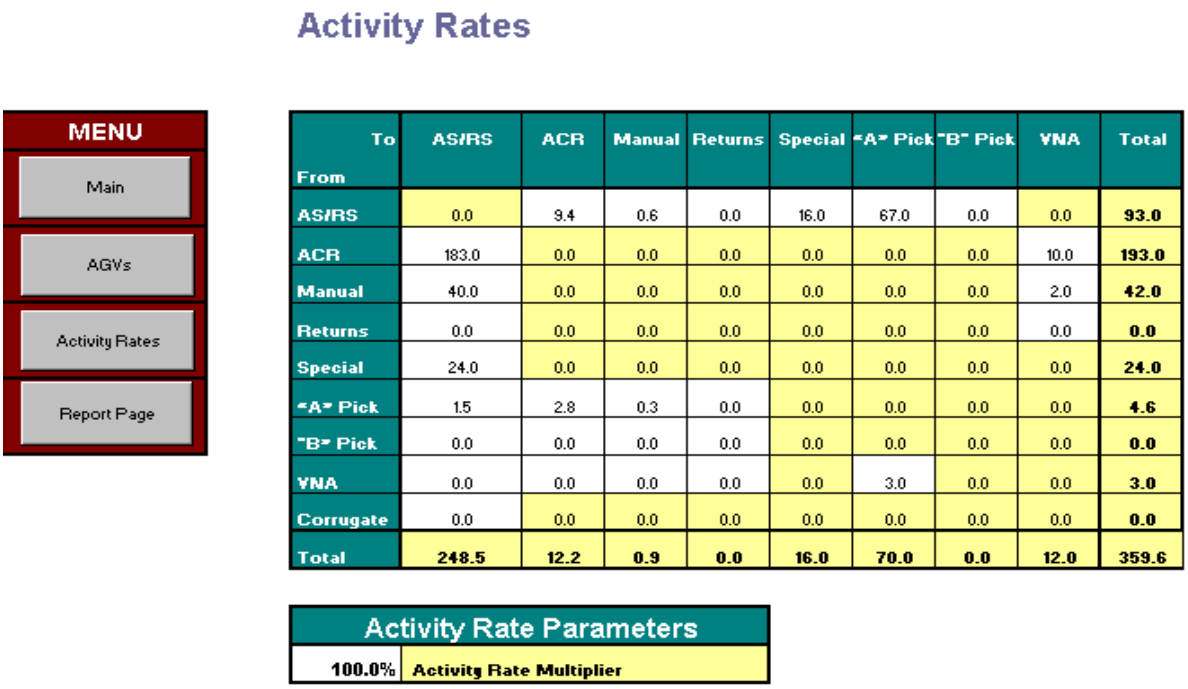
Simulation and User Interface

- The working directory is where the "model.dir" and the "model.exe" files are contained. The data files will also be written to this directory.

- Scenario is a descriptive text string. This is not used in the simulation model but was inserted to assist the user for documentation.

- The random number string is used to generate different random number streams in the model.
- The warm-up is the length of time the model runs, after which the statistics are reset to help achieve a "steady state" system.
- Run length is the length of time after the warm-up that the model is run.

The *Required Activity* sheet is shown below:



To / From	AS/RS	ACR	Manual	Returns	Special	"A" Pick	"B" Pick	VNA	Total
AS/RS	0.0	9.4	0.6	0.0	16.0	67.0	0.0	0.0	**93.0**
ACR	183.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	**193.0**
Manual	40.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	**42.0**
Returns	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Special	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**24.0**
"A" Pick	1.5	2.8	0.3	0.0	0.0	0.0	0.0	0.0	**4.6**
"B" Pick	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
VNA	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	**3.0**
Corrugate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
Total	**248.5**	**12.2**	**0.9**	**0.0**	**16.0**	**70.0**	**0.0**	**12.0**	**359.6**

Activity Rate Parameters	
100.0%	Activity Rate Multiplier

- The "From / To" chart is the activity of loads per hour from each of the areas to each of the areas.
- The Activity Rate Multiplier is used to increase/decrease the rates shown in the chart. If the rate multiplier is set to 100% and the model will use the rates shown in the chart.

The *AGV input* sheet is shown below:

AGVs

MENU
Main
AGVs
Activity Rates
Report Page

AGV Parameters		
33	Total Number of AGVs	
Value	Units	AGV Motion Parameters
1.0	fpss	Acceleration
1.0	fpss	Deceleration
200.0	fpm	Forward Velocity
100.0	fpm	Forward Curve Velocity
180.0	fpm	Forward Spur Velocity
200.0	fpm	Reverse Velocity
100.0	fpm	Reverse Curve Velocity
180.0	fpm	Reverse Spur Velocity
9.0	deg/sec	Rotate Velocity
6.5	sec	Pickup/Setdown Time
Value	Units	AGV Battery Changeout Parameters
480.0	min	Time Between Battery Change-outs
15.0	min	Time For Battery Change-out
Value	Units	Sizing Station/Rework Parameters
6.9	%	Sizing Station Failure Rate
95.6	sec	Rework Time

- The Total Number of AGVs is the quantity of active AGVs in the model. The motion parameters are the speed, acceleration / deceleration for the AGVs.
- The time between battery change-outs is how often the batteries need to be changed and the time for battery change-out is the length of time to complete the operation.
- The Sizing Station Failure Rate is the percent of loads that fail this operation. The Rework Time is the length of time that the load & AGV spend in the rework stand if they fail at the sizing station.

The *report sheet* is generated once the model is run to completion. An example of the model output sheet is show below:

SCENARIO	Test # HK System
RANDOM SEED NUMBER	1
WARM UP PERIOD	2
RUN LENGTH	24

Return To

Simulation Throughput Results (Average Loads/Hour)										
To / From	ASRS	ACR	Manual	West Receiving	Special	A-Pick	B-Pick	VNA	Total	Expected
AS/RS	0	4.5	0.7	0	10.8	64.5	0	0	80.5	84
ACR	155.9	0	0	0	0	0	0	0	155.9	158
Manual	0.7	0	0	0	0	0	0	1.7	2.4	2.6
West Receiving	0.5	0	0	0	0	0	0	1.5	2	2
Special	12.1	0	0	0	0	0	0	0	12.1	12
A-Pick	7.7	2.9	0.2	0	0	0	0	0	10.8	11.1
B-Pick	0	0	0	0	0	0	0	0	0	0
VNA	0	0	0	0	0	0	0	0	0	0
Incentory control	0	0	0	0	0	0	0	0	0	0
Total	176.9	7.4	0.9	0	10.8	64.5	0	3.2	263.7	
Expected	180.6	6.8	1.3	0	12	67	0	2	269.7	

AGV Results	Value	Unit	Expected
AGV Utilization:	97.4	Percent	---
Time Waiting for AGV Pick-up:	7.1	Minutes	---
Time Waiting at ACR for AGV Pick-up:	9.5	Minutes	---
Percent of Loads that Failed Sizing:	4	Percent	4.4
Avg. # of Loads Waiting for ACR Stand:	10.1	Loads	---

Average AGV Movement Time (Minutes)								
To / From	ASRS	ACR	Manual	Returns	Special	A-Pick	B-Pick	VNA
AS/RS	0	3.2	3.7	0	3.3	2.2	0	0
ACR	4.1	0	0	0	0	0	0	0
Manual	4.7	0	0	0	0	0	0	1.2
West Receiving	6.1	0	0	0	0	0	0	1.3
Special	5.1	0	0	0	0	0	0	0
A-Pick	7.9	4.5	3.1	0	0	0	0	0
B-Pick	0	0	0	0	0	0	0	0
VNA	0	0	0	0	0	0	0	0
Inventory Control	0	0	0	0	0	0	0	0