EFFICIENTLY MODELING WAREHOUSE SYSTEMS

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ABSTRACT

Ryder System, Inc. has created a flexible simulation model to be used as an engineering tool to validate automated warehouse designs, predict resource requirements, and determine operational throughput capacities for its E-channel operations. The model's flexible demand generation and operating parameters allow potential clients to quickly witness "what-if scenarios" of their specific operations. The data parameterization of common system attributes, and specific applications of the model will be presented. The benefits and limitations of template modeling will be discussed.

INTRODUCTION

The proliferation of e-business has demanded that supply-chains include increasing performance on distribution and order fulfillment operations. Simulation has aided in meeting this demand from both engineering solution design and business development perspectives.

Ryder System is a leading provider of logistics services and complete supply chain solutions. Ryder operates approximately 300 warehouses within its network of domestic facilities. Ryder launched its E-commerce division in August 1999. Ryder E-Channel solutions include a network of distribution faculties providing distribution and fulfillment services to B to B and B to C clients.

In an effort to validate the design and operations of a Dallas E-channel facility, Ryder and AutoSimulations developed a flexible template simulation model. The facility is 175,000 sf and contains multiple pick and storage modules as well an automated conveyor and sortation system. An existing 3-D AutoCad file was used to create the 3-D animation in this model.

1   FLEXIBLE SIMULATION MODEL

The application of simulation software packages to manufacturing problems typically presents two conflicting is-sues. Pure simulators traditionally are easy to use, but much is lost in the area of flexibility and model accuracy. On the other hand, simulation languages greatly improve model flexibility and accuracy, but ease-of-use is sacrificed. By utilizing a powerful simulation language and limiting the problem domain, the best of both worlds is achieved, as shown within this template model.

The scope of the template model is limited to the domain of a typical warehouse layout, and the boundaries implied by the data input files. These boundaries include a wide range of operational parameters for all areas of the warehouse. The warehouse template model, built using AutoMod, provides for all possible boundary combinations. The simulation software provides the flexibility needed to accurately develop the warehouse 'template' model. The interface associated with the software provides for ease-of-use in setting up scenarios and running the model.

The model design implements a customized Excel user interface providing the data sheets used to define each simulation scenario. Each workbook has customized functionality that downloads the spreadsheet data to the simulation model, and starts the simulation application. During the simulation run, a full 3-D animation of the warehouse scenario is shown. When the simulation model has completed running the defined scenario, it feeds statistical output data from the simulation model back to the Excel workbook. This design provides input capabilities for setting up a seemingly unlimited number of customer scenarios, and provides graphical and statistical output for each.

Because the model was designed and developed to handle all data input combinations, the model user never needs to edit or compile model code. Scenarios can quickly be set up and run to get comparative results and see what would likely happen in the real warehouse.

2   DATA INPUT

The Excel control workbook (shown in Figure 1) logically groups data input parameters into five different worksheets,

comprising a data set. In addition, special customized procedures were written, using visual basic for applications (VBA), to link the simulation model with the workbook. This provides the functionality to download the data set to the simulation model, launch the simulation run, and retrieve customized output statistics generated by the model.
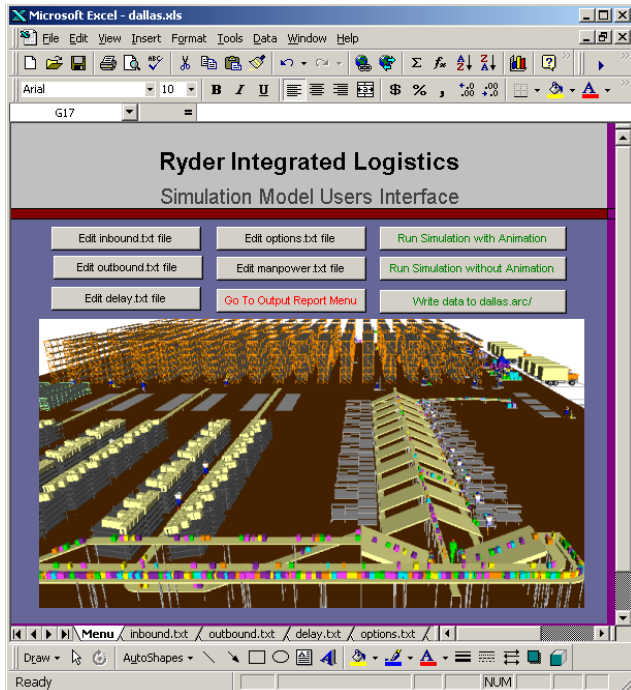

Figure 1: Customized Excel User Interface

Distribution Centers have many common attributes and functionality. The data input sheets have been organized to accommodate input values for these common attributes.

2.1 Inbound Activity

All distribution centers must receive and store product. Typically, trucks arrive at a distribution center with pallets of product to be delivered. Each truck arrives with one or more advanced shipping notice (ASN). Each ASN lists what product will be delivered. The ASN will include one or more shippable kitted unit (SKU) and the number of units (or quantity) for each SKU. SKU's are typically stored in cartons, which are carried on pallets.

The inbound data file was developed to allow simulation input for these parameters. Since there may be a high degree of randomness associated with specific parameters, random number distributions can be specified and used for each parameter. These parameters include:

- Trucks per day
- Hour of truck arrival
- ASN's per truck
- Pallets per truck
- Cartons per pallet
- SKU's per ASN
- Units per SKU
- Product storage area

Most of the raw data is readily available. The selection of which random number distributions to use is aided by software packages such as "ExpertFit" or "StatFit", which evaluates the raw event data and provides a list of the best random distributions and respective arguments to use.

2.2 Outbound Orders

Product stored in distribution centers must eventually leave the warehouse. Orders are used to create outbound product activity. Typically, orders are received and shipped the same day. Orders are generated by customer demand. An order may consist of one or more line. Each line lists an SKU and the quantity needed.

Orders accumulate until a threshold has been exceeded. At this point a wave is created. A wave consists of a group of orders that must be picked, packaged, and loaded onto an outbound truck. Waves are picked in the order of creation (picking will not start for wave 2, until wave 1 has been picked). There may be many waves created and processed in a day, depending on the orders for that day.

Picking is done by workers who are given picking labels and directed by RF instructions. Items are picked from storage racks, bins, and other locations, and routed to a staging area. At the staging area, they are removed from the carton, and routed to one of the defined packaging stations. All of the items in an order will route to the same packaging station. Packaging stations process or packages all of the items in an order, and send the resulting package to the shipping area. Outbound packages are assembled on pallets, before being loaded onto an outbound truck.

The outbound data file was developed to allow simulation input for these parameters. Random number distributions can also be specified for each parameter. The outbound parameters include:

- Orders per day
- Lines per order
- Units per line
- Maximum units per pallet (staging)
- Packaging units per box
- Packaging boxes per pallet
- Wave creation threshold
- Outbound trucks per day
- Pallets per outbound truck
- Picking product locations

2.3 Manpower Requirements

Typical distribution centers require workers to perform various operations. Workers are needed in the receiving area to unload the trucks and store the product. They are needed in the outbound area to pick and stage the product. They are needed to package the product, and load the outbound trucks.

The manpower data file allows you to set finite capacity constraints on each of the worker types. This means that you can define operator types, and specify the number available for each shift. The simulation model will operate with the specified number of workers.

This input file provides input to specify a worker type, and the quantity of workers on each of the available operating shifts.

2.4 Productivity Measures

Time studies are done to determine time requirements needed to perform various tasks within the distribution center. These time studies yield a random distribution and the respective arguments for the associated task. The resulting productivity measure is used as data input into the simulation model. Productivity measures for the template simulation model include:

- Product picking for each area
- Pallet drop off for each area
- Conveyor induction
- Packaging
- Pallet Creation
- Loading pallets onto the truck
- Unloading pallets from the truck
- Pallet Breakdown
- Paperwork for various activities

Productivity measures that aren't included in the data sheet can be added, but must also be added to the simulation model.

2.5 Miscellaneous Options

Input for other miscellaneous options have been included on a separate input sheet. These options provide the ability to specify the length of the simulation run and other parameters. These options include:

- Simulation warmup
- Simulation run length
- Batching efficiency for each area
- Next wave release threshold (when can the next wave be released from the stage area to the packaging area)

3 RUNNING THE SIMULATION

Data sets are exported to text files which are read in and used by the simulation model. The simulation model is launched from the Excel control sheet, which brings up the simulation application window shown in Figure 2.
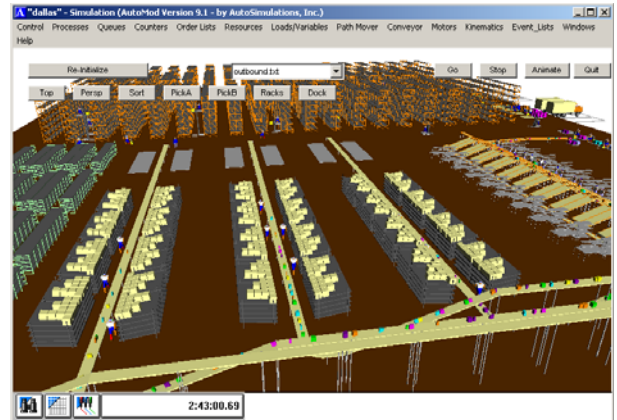

Figure 2: Simulation application window

The Simulation application window provides the 3-d animation of the distribution center, and illustrates the data set as it is running. The ability to graphically display the activity in the distribution center has proven to be a valuable sales tool, and a useful analytical tool.

Options are included in the simulation application window that allow users to:

- Toggle animation on and off
- go to a pre-defined graphical view
- Start and pause the simulation run
- View any of the input files
- View or print a custom report
- Track a specific load (carton, sku, or pallet)
- Quit the simulation run and return control to Excel

4 MODEL OUTPUT

The simulation model provides both graphical and statistical output. The graphical output occurs automatically, as it is tied into the simulation model. In addition, postprocessed graphical files are written by the model and can be used to generate ".avi" movies with special scripts.

Statistical output reports can be accessed as the model is running, or after control has been returned to Excel. Several customized output reports are written by the simulation model, and loaded back to the Excel control workbook.

4.1 Inbound Report

The inbound file is used to report statistics relating to product coming into the distribution center. This report in-

cludes statistics for each inbound truck. The following information is reported for each truck that arrives at the distribution center:

- Day it arrived
- Arrival Sequence for the day
- Number of ASN's it contained
- Total number of SKU's unloaded
- Total number of cartons unloaded
- Total number of units unloaded
- Time to unload the truck

4.2 Outbound Report

The outbound file is used to report statistics relating to product leaving the distribution center. This report is broken out to report wave creation and completion statistics. For each wave (of each day), the following information is reported:

- Day
- Wave number
- Total orders in the wave
- Total single orders in the wave
- Total multiple orders in the wave
- Total pick time for the wave
- Total lines shipped
- Total number of units in the wave
- Total number of resulting outbound cases
- Time required to pick the wave

4.3 Manpower Report

The manpower file reports statistics relating to each of the resource types defined. This report details the following output information:

- Maximum number available
- Maximum number used
- Average number required (busy)
- Average number available per shift
- Combined Utilization

From this output information, assumptions about resource requirements can easily be made.

5 MODEL AS MARKETING/ANALYSIS TOOL

The easy to use and accurate simulation model has gained acceptance within the logistics field as an analytical tool. In addition, it is being used as a business development tool for sales and pre-sales opportunities.

5.1 Business Development Tool

Business development within logistics involves developing detailed responses to requests for pricing (RFP's). Proposed supply chain/logistics solutions are then typically presented to key decision makers of the organization seeking third party logistics solutions and services. In solutions where Ryder E-channel solutions include warehouse and fulfillment order processing, this simulation model has proven effective to demonstrate the proposed solution.

Model flexibility allows for simulation iterations to be run to demonstrate an understanding of the potential client's business using the order volumes associated with the clients warehouse activities. Inbound and outbound volumes can be input into the model as variable distributions, which represent client volumes accurately.

Ryder has used Automod effectively as a business development tool in the following situations:

A. Simulation Opportunity

A high technology aerospace prospect has a business requirement to provide critical replacement parts to their customers immediately when a component fails in the field. Their business depends on critical parts being shipped at a moments notice, 24 hours a day, 7 days a week. The ability to perform this service will be carefully evaluated with order volume having an extremely high degree of variability, and to complete order processing to meet predetermined carrier cut-off times.

Simulation Results

Flexible input modeling describe earlier allowed Ryder to simulated many activity levels as "what if scenarios" which demonstrated the ability to shift resources effectively to fulfill the required order volumes. In this case, we can shift orders to arrive at any time during the day and vary the magnitudes by revising the appropriate Excel inputs. This capability provides a means for an extremely effective presentation, perhaps providing the necessary competitive edge to win the business.

B. Simulation Opportunity

One client questioned: "Our orders at the end of the month, have many more units than represented in your model."

Simulation Results

During the presentation, the client provided the inputs to model the order volume consistent with the last day of a month. Model results proved the resources and

proposed process would be able to process month end volumes. This accelerated the model validation and buy-in from a client with little previous exposure to simulation.

C. Simulation Opportunity

Ryder E-channel solutions targets e-tailers within the consumer products industry. A women's active-wear apparel provider required the fulfillment of a large percentage of the customer orders during the holiday season.

Simulation Results

The model's flexibility in timing, resources, and activity levels allowed the client's peak season scenario to be simulated by altering input parameters established in the average month simulation scenario.

This was very effective in increasing client confidence in Ryder's ability to plan for the required resources well in advance. Labor availability is a common concern within distribution center and warehouse environments in general, and more so during holiday peak seasons.

One of the compelling reasons for an organization to outsource is that they desire to concentrate on their core business functions. The simulation model has proven to be an effective tool in predicting varying resource requirements, which assists in determining outsourcing requirements.

This simulation model has also proven to be effective prior to and during the RFP phase of potential sales. AVI movies have been created and viewed via e-mail , CD, or web site to demonstrate the capability of simulating operations within Ryder's infrastructure of facilities. During customer presentations, the 3-D animation has proved extremely valuable. The level of client engagement increases dramatically after they see the animation of their own operations. The model distinguishes client product by color, so they see their own volumes relative to other clients' volume. Without the 3-D animation, this model would have little impact on our logistics solutions.

5.2 Internal Analytical Tool

Providers of warehousing and distribution services need to know the capacity of their operations. Ryder E-channel solutions operate a network of facilities designed to provide distribution and order fulfillment services to multiple clients within the same facility. Prior to marketing services of E-channel facilities, Ryder established the capacity of its E-Channel facilities using this simulation model.

E-commerce statistical data regarding order profiles of E-tailers was acquired and prospective customer volumes were modeled at several levels of activities. Facility capacities were determined by enabling all resources in peak activity scenarios, and a "best case" capacity was determined across 1, 2, and 3 shift scenarios as well as 5 and 6 day work weeks. Inputs were revised for less than optimal situations. These inputs include productivity rates, wave overlap factors, and order batching parameters. The group operating the facilities controlled modeling inputs that would determine the volume levels to be used by the business development team.

The model has been extremely cost effective in modeling "what if" scenarios for our operations group. Many iterations using demands driven by variable distributions have been run to aid in decisions involving the purchase of forklift vehicle and conveyance equipment, as well as employee hiring.

Providers of distribution services need to thoroughly understand a wide range of cost components in order to price business opportunities effectively. The simulation model has been used to evaluate manpower and capital equipment requirements while meeting all of the performance requirements of potential clients.

Order volume variables and the wave release functionality within this model are particularly effective in this area. Multiple scenarios can be run allowing pricing based on averages or specific ranges of volume assumptions. Wave creation is simulated with the exact functionality used by the Warehouse Management System, allowing wave creation to be dependent upon the number of pack stations, order types, and threshold levels of orders per pack station. The model is then used as a tool to aid in pricing strategy development.

6 CONCLUSIONS

The flexible simulation model was developed jointly by Ryder and AutoSimulations, and was initially intended to validate a distribution design concept and determine operational throughput capacities of Ryder's network of E-Channel distribution centers.

The model was developed within just a few weeks, and during that time it became apparent the model could also be used within the business development process. The Customized Excel User Interface provided flexibility that allowed new business scenarios and activity levels to be simulated within minutes. The 3-D graphical interface capabilities provided the animation capabilities required to engage logistics professionals with little prior simulation experience.

6.1 Benefits – Business Development

- Simulation was used early in the business development process and made available to the niche market.

- During client presentations and the sales process, the model could be run depicting normal and extreme business activity levels.
- The ability to run " what if" scenarios within a few minutes increased the value of the simulation tool, and allowed immediate input from business stakeholders.

6.2 Benefits – Analytical Tool

- The model results validated the facility design, capital investment, and facility capacities.
- The flexible Excel user interface provided a means for operations to model infinite "what if" scenarios.
- The model was a tool to provide more effective pricing strategies.

6.3 Model **Drawbacks**

- The animation could have gone further within some operations. For example, during receiving and inspection, warehouse employees are standing still when they are performing QA, counting, scanning, and checking

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