FINAL REPORT

for

Demonstration of Global Supply Chains with Intermodal Transportation and Decision Support for Small and Medium Business

Funded by the National Center for Intermodal Transportation

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INDUSTRIAL & SYSTEMS ENGINEERING

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1. INTRODUCTION

1.1 Globalization of the US Furniture Industry

The globalization has exposed all companies, large or small, to global competition and cooperation. The US furniture industry is not an exception in this process. Table 1 provides an overall picture of the evolvement of the US residential furniture industry about 10 years with domestic and import shipments.

Table 1: Shipments of wood and upholstered residential furniture in the US (Epperson, 2009)

	1999 (Million)	**2008 (Million)**	**% Change**
Wood: Domestic	$12,996	$6,409	-50.7%
Wood: Imports	$5,303	$9,609	81.2%
Upholstered: Domestic	$9,601	$8,325	-13.3%
Upholstered: Imports	$986	$2,928	197.0%
Upholstered: Imports from China	$101	$2,093	1972.3%

In the US, upholstered furniture imported from China has grown at the annual rate of over the last decade. Before 2005, more than 80% of imported upholstery was leather. In 2006, only just over 60% of upholstery imports from China were leather. Fabric upholstery imports nearly tripled from 2005 to about $625 million. Fully assembled upholstered furniture from China grew 37.9% in 2006 (Epperson 2007). It is expected that the growth of upholstery imports from China will continue, especially for fabric upholstered furniture. Table 1 demonstrates that imports have a large share in the furniture market in the US and this share is growing. There are three major reasons why imports have become so importation for the US furniture industry over the past 15 years:

1. The globalization forces have removed the protection over US furniture companies and exposed them to global competition (Schuler and Beuhlmann, 2003).
2. Containerized shipping technology has significantly reduced global shipping costs (Schuler and Beuhlmann, 2003).
3. Production of furniture is labor intensive. The labor cost in the US is much higher than many developing countries.

1.2 Supply Chain Management for Small-sized Furniture Companies

Northeast Mississippi has the biggest upholstered furniture manufacturing cluster in the US, which has about 200 companies. Most of these manufacturers are small- and medium-sized companies with 300 and fewer employees. An efficient supply chain is the key for furniture companies to survive and prosper in the global competition faced by the furniture industry (Bryson et al. 2003). However, the global supply chain process is so complicated and involves multiple logistics/transportation companies, different insurance companies, various policies and laws over countries, and typical complex information systems. Our survey on Mississippi furniture companies, including *Airline Manufacturing*, *Lane Furniture*, *Flexsteel*, *Tupelo Manufacturing*, and *United Furniture Industries*, shows that most of them do not understand and do not know how to operate their supply chain. They usually order the materials from a third logistic party and focus the negotiation on prices. The finding is different from big companies such as Ashley, which is operating a very efficient global supply chain (Gilmore, 2006). In this research, we can demonstrate that better management of their own supply chain will enhance their competitiveness by better controlling their inventory, reducing the intermodal transportation via working together with a third-party logistics company, and minimizing lead time and avoiding risk by tracing the log of orders. All those benefits require a close relationship and alliance with partners along the industry value chain, from upstream suppliers to freight carriers to retailers (Holweg and Bicheno, 2002). Small business owners can also adjust their market strategies based on their supply chain operations. To survive and grow in this dynamic environment, all players in the industry need to understand, define, develop, and maintain their competitiveness via tuning their supply chains. We believe that a better understanding of their supply chains will help Mississippi furniture companies work together with logistics companies to improve the efficiency, specifically the cost and lead time of their products.

1.3 Intermodal Problem in the Furniture Industry

A long supply chain across borders typically involves multiple transportation modes (Prater et al. 2001). A typical intermodal shipment from Asia to a furniture company located in Northeast Mississippi involves three transportation modes: ocean line, railway, and highway. Companies could order supplies or finished furniture from Asia, mainly China and Vietnam. Then, the standard containers with cargos are transported from overseas to US ports, such as Long Beach, CA, through steam line. Followed by the steam line transportation, containers could be shipped to Memphis, TN via railways, and then go to the company in trucks.

There are different business models for furniture imports from Asia to the U.S.

(Bryson et al., 2003): manufacturer outsourcing model, direct investment model, direct sales model, and agent outsourcing model. Different from big companies such as Ashley, the small volume of most Mississippi furniture companies cannot justify the overhead costs of direct contact with Asian manufacturers or direct investment in Asia. They also do not have experience and expertise about how to manage a global supply chain and eve does not understand the complications of a global supply chain and involved intermodal issues along the chain (Navas, 2005). An international furniture trade agent, which could be a third party logistics provider (3PL), typically deals with the international transaction and logistics for small- and medium- sized furniture companies (Terry, 2007).

2. RESEARCH OBJECTIVES

The objective of this research is to develop a simulation model with geospatial information to simulate a typical global supply chain related to a small/medium business in the United States for logistics operations, professional training, academic education, and decision support therefore enhancing their competitiveness in global competition. A typical model is established using the example of Mississippi furniture industry. Through the animations and results of the simulation, small business owners can understand the mechanism of global supply chain and realize opportunities in supply chain and intermodal management instead of just concentrating the company's own in-house operations.

In addition, the simulation model is established considering the impacts of intermodal transportation that involves three transportation modes, ocean steamship lines, railways, and highways along a global supply chain from oversea suppliers to the company and then to final customers. The understanding and support of intermodal transportation from business will be crucial for the promotion of intermodal transportation. Specific transportation policies targeting the supply chain could be more effective in identifying and subsequently shifting transport from road to intermodal (Tsamboulas et al., 2007). With additional help of Geographic Information System (GIS), the model in this research can visually display the impact of intermodal transportation on global supply chain management and can be served as an educational tool to assist small/medium business to understand intermodal transportation and their global supply chain, including both inbound and outbound logistics. Besides, the simulation model can also be used to demonstrate improvement opportunity to furniture companies by simulating alternatives to their current supply chain operation. The alternatives are compared to the current chains based on performance measures.

3. ANALYTICAL TOOLS AND METHODOLOGIES

3.1 Discrete-Event Simulation

Simulation is the imitation of a dynamic system using a computer program and can be used to demonstrate, evaluate, and improve system performance (Harrell et al., 2004). Simulation started its commercial applications in the 1960s and is currently a popular decision-making tool in both manufacturing and service industries, especially for complex systems that cannot be represented by analytical models. In additional to providing decision support, simulation provides visual animation that stimulates interest among audience and improves communication for complex system dynamics (Banks et al., 2004).

Simulation can be used to evaluate and analyze alternatives of supply chain design and operations with multiple transportation modes. In the literature, simulation models have been developed for overall intermodal transportation in one region or nation from the planning viewpoint (e.g., Tan et al. 2004). There are also numerous advanced decision making models (e.g., Jin et al. 2009) addressing design and operational problems involving intermodal transportation for complicated and large-scaled supply chains faced by big companies. This research explores the logistics needs of small/ medium business and extends the intermodal transportation and supply chain management research into the regime of small/ medium business.

In this project, we simulate the dynamics of the global supply chain for a typical Mississippi furniture company through ProModel, one of the most popular and powerful simulation software (ProModel, 1997). The model simulates a typical global supply chain to the importance and major steps of a global supply chain faced by small- or medium-sized furniture companies. The visual animation encourages them to adopt innovations to improve their supply chain design and management. From a simulation perspective, a system consists of entities, activities, resources, and controls. These elements define who, what, where, when, and how of entity processing (Harrell et al., 2004). In this project, the entities are supplies or finished furniture moving along the supply chain. The activities include loading, unloading, transportation, manufacturing, swelling, and other operations. The resources include ships, trains, trucks, manufacturing plants, warehouse, and personnel. The controls consist of arrival and departures scheduling, loading and unloading planning, etc.

3.2 Geographic Information Systems in Supply Chain Management

Geographic Information Systems (GIS) is a collection of computer hardware, software, and geographic data for capturing, managing, analyzing, and displaying all forms of geographically referenced information (Chang, 2006). Geographic information is an important attribute of activities, policies, and plans (Longley et al., 2006). GIS can help decision makings involving geography, such as choosing sites, targeting market segments, planning distribution networks, responding to emergencies, redrawing country boundaries, and many others. In this project, GIS maps are used in the simulation. GIS maps also provide geographic data for simulation model development, such as distance information and the optimal and economic routes. The visual display by GIS maps will help audience better understand the whole furniture supply chain and to find some potential business opportunities

4. INVESTIGATIONS AND ANALYSIS OF SUPPLY CHAINS OF MISSISSIPPI FURNITURE INDUSTRY

The global supply chain investigations and analysis are conducted based on the information collected from a survey on several Mississippi furniture companies including *Airline Manufacturing*, *Lane Furniture*, *Flexsteel*, *Tupelo Manufacturing*, and *United Furniture Industries*, and the data provided by Diversified Global Logistics Inc (DGL), which is a member of the World Cargo Alliance. The headquarter of DGL is located in Memphis, TN. DGL is a quality provider of supply chain services to several selected niche industry/business segments, including the furniture industry in Mississippi. It provides tailor-made global services including domestic and worldwide air and ocean transportation, customs clearance, management, warehousing, distribution and fulfillment solutions.

Based on the analysis of gathered information, a typical supply chain for a Mississippi furniture manufacturer is illustrated in Figures 1-4. Triggered by the inventory level or consumers' demand, the manufacturer places a purchase order to either a buyer (agent) or a supplier in Asia. A copy goes to a freight forwarder, who in turn calls the shipper to verify the order and the shipping date. The freight forwarder picks up freight in a container or truckload depending on the order size and books ships with steam ship lines. At this point, the forwarder may collect smaller shipments from other customers and consolidate them into a container load. The Automated Manifesting System (AMS) is submitted 24 hours prior to loading the container on the vessel that it is booked on. Failure to complete the AMS procedure will halt the container being loaded on the booking vessel. There are primarily four routes used for freight coming to Mississippi: Delta Port Canada – Chicago – Memphis, West Coast (Seattle, San Francisco, Long Beach) – Memphis, East Coast (New Jersey, New York, Norfolk, Charleston) – Memphis, and Gulf to Memphis/Mississippi. The East Coast and Gulf are considered the slowest of the four possible routes. When the freight is seven days off the US coast, the US Customs entry can be submitted to set up clearance of the cargo. When the cargo clears US Customs, the cargo is allowed to be delivered to the customer's facility. This delivery is either contracted through the steam ship line or by a local drayage company. The container must be removed from the rail yard in 48 hours including weekends. Otherwise, demurrage will begin. Containers arriving at the consignee's dock must be unloaded within 2 hours unless prior arrangements have been agreed on. On the distribution side, furniture companies have agreements with firms that specifically deliver furniture throughout the USA. These carriers will build loads using various shippers' furniture. Figures 1-4 illustrate the flow with the estimated lead time and cost for each step. The cost data of some steps cannot be collected and need to be estimated by an indirect way in the simulation. In order to build the simulation model, sets of data were collected to build entities, routes, resources, inventory accumulation, cost calculation, and so on. Tables 2 and 3 summarize part of information provided by DGL

Table 2: Relevant Import and Export Ports

Sea Way Transportation Ports			
Origins		**Destinations**	
Hong Kong	Tianjin	Philadelphia	High Point
Yantai	Dalian	Houston	Roanoke
Qingdao	Singapore	Toronto	Martinsville
Shanghai	Semerang	Nashville	Mountain View
Shantou	Bangkok	Baltimore	Los Angles
Xiamen	Fangcheng	Charlotte cy	Memphis ramp
Ho Chi Minh	Huangpu	Atlanta ramp	Albertville
Jakarta	Nansha	Tampa, Fl	Chicago
Shenzhen	Port Kelang	Haleyville	Jacksonville, Fl

Table 3: Transportation Cost Estimates from DGL

	Cost (40'GP) $/container	Cost (40'HQ) $/container	Door Trucking cost $/container +tax
Min	2,040	2,122	$123+27%
Max	4,550	4,790	$588+25%
Average	3,527	3,692	

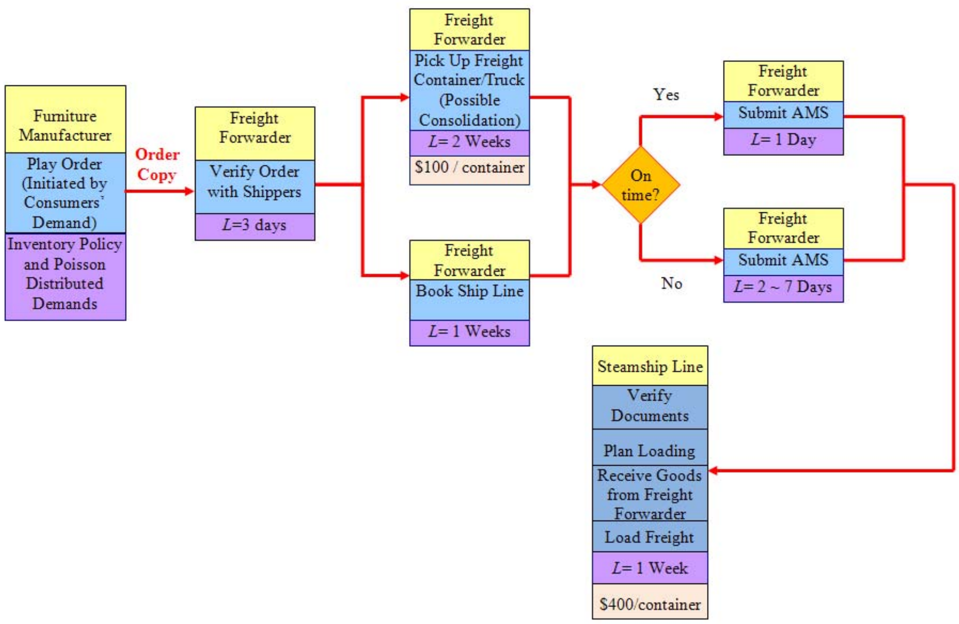

Figure 1: Supply Chain Diagram (Part 1: Order Placement)

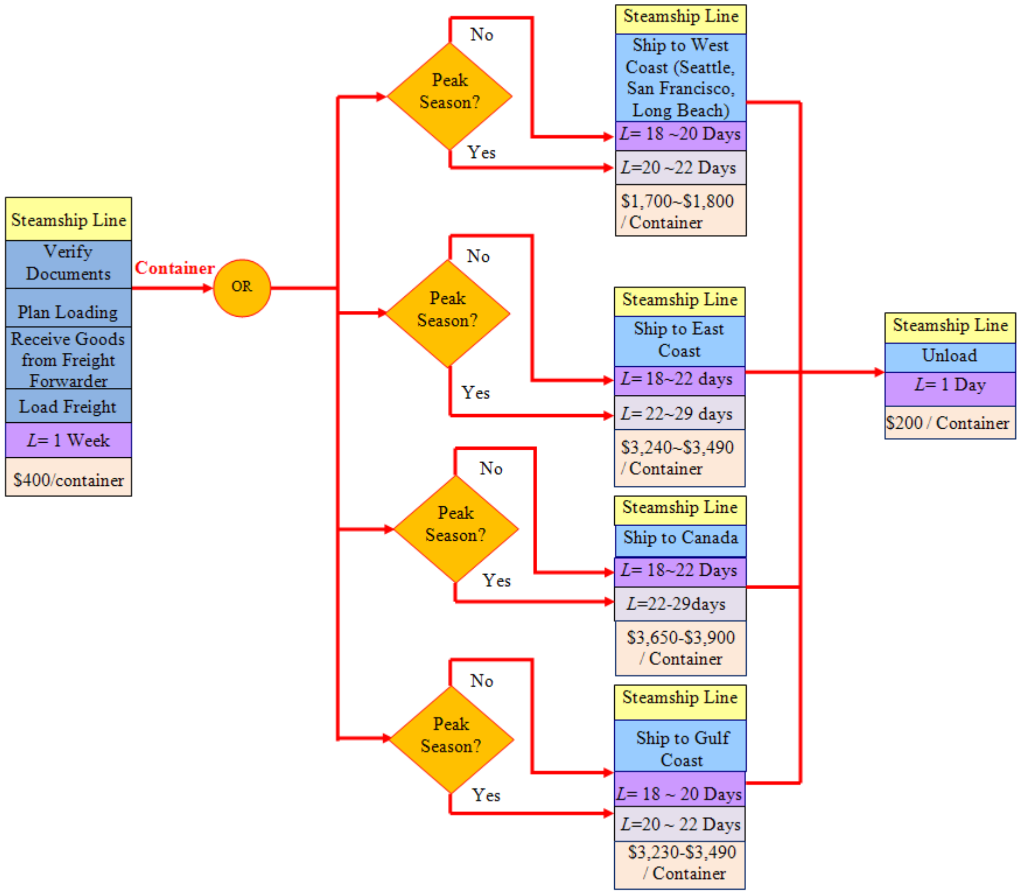

Figure 2: Supply Chain Diagram (Part 2: Ocean Shipping)

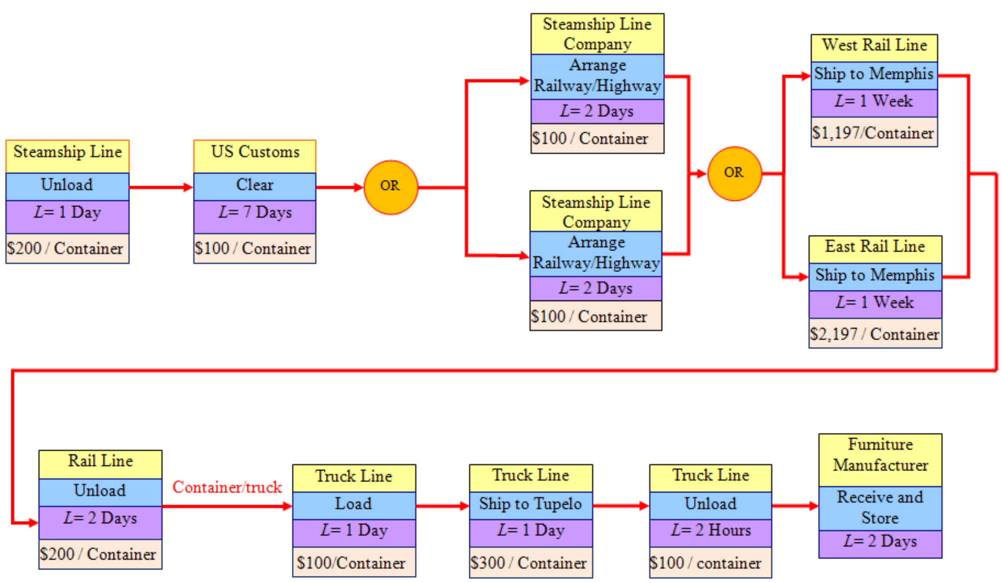

Figure 3: Supply Chain Diagram (Part 3: from US Customs to Manufacturer)

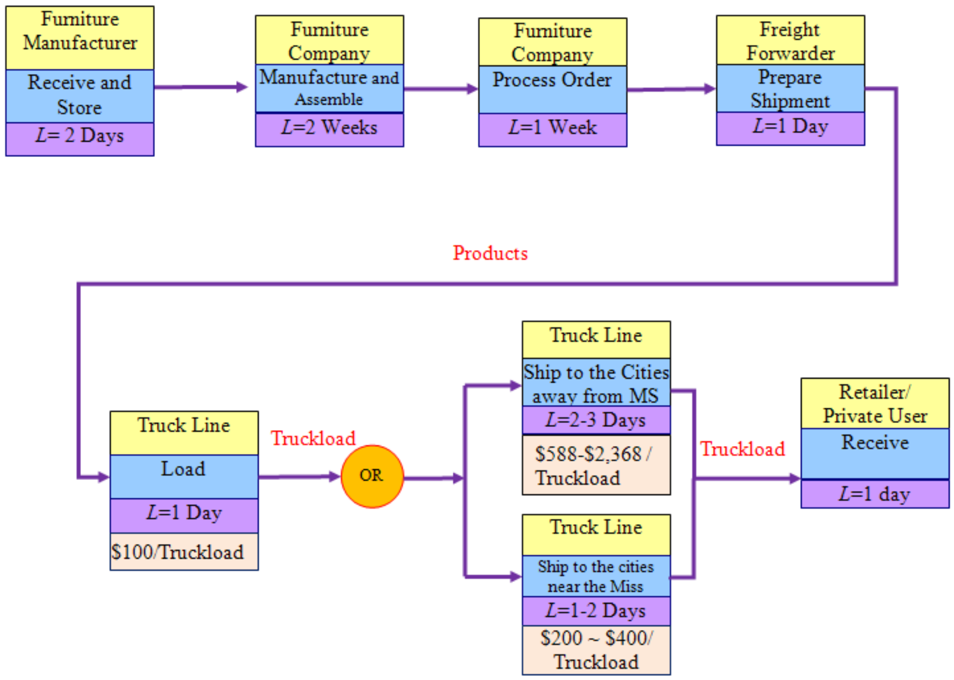

Figure 4: Supply Chain Diagram (Part 4: Manufacturing and Goods Distribution)

5. THE GLOBAL SUPPLY CHAIN SIMULATION

5.1 Simulation Assumptions and Estimations

In order to capture the main characteristics of the supply chain, the simulation model uses the following assumptions based on our interactions with furniture manufacturers and logistics companies:

1. The inter-arrival time of orders from furniture dealers or customers for the manufacturer is assumed to be exponentially distributed because of the large customer base with independent demands.
2. The port and railway ramp have large capability compared to the needs of this specific supply chain.
3. Unloading time is uniformly distributed.
4. The typical supply chain starts from Shanghai, China.
5. All goods are shipped to Long Beach, US.
6. The manufacturer is located in Tupelo, MS.
7. The (q, r) inventory policy in a continuous-review fashion (Askin and Goldberg, 2001) is used to issue orders on suppliers and trigger an inbound shipment.
8. There are two types of imports: material supplies and finished furniture. Material supplies need to be assembled in the manufacturing plant. The imports of

finished furniture can be used to meet customer needs directly without any manufacturing.

9. The US market is approximated by local markets at eleven big cities: Washington DC, New York City, Chicago, Minneapolis, Seattle, Los Angles, Phoenix, Denver, Houston, Atlanta, and Miami.
10. All containers are fully-loaded.
11. Railways are used to transport supplies or finished furniture from Long Beach, CA to Memphis, TN.
12. Highways are used to transport supplies or finished furniture from Memphis, TN to Tupelo, MS.
13. Only highways are used in the distribution of finished furniture to major markets.

5.2 Basic Model Development

The current global supply chain of a furniture manufacturer located in Tupelo, MS is simulated as the basic model in this project. The manufacturer, its oversea supplier and markets are simulated based on the supply chain flow charts in Subsection 4.1 and assumptions in Subsection 5.1. Raw materials or finished goods are consolidated as containers and imported from Shanghai, China via steam ships to Long Beach, CA. The containers are then shipped via railways to Memphis, TN, an important logistic hub that is close to Mississippi. Trucks are used to transport containers from Memphis, TN to the manufacturer in Tupelo, MS. The manufacturer produces furniture from raw martial or just holds inventory when the import is already finished furniture. Finished furniture is then shipped to the major markets upon the demands of retailers or distributors.

In discrete-event simulation, entities are objects being processed or transported. For this simulation, the definitions of entities are provided in Table 4. The major entities include raw material (RM) imported from Asia, imported finished goods, and manufactured furniture. Other entities are for demands, inventory levels, and backordered units.

Table 4: Entity Definition

Name	(fpm)	Stats
RM	Time	Series
Finished_Goods	Time	Series
Furniture	Time	Series
Demand_M	Time	Series
Evaluation_M	Time	Series
Backorder_Item_M	Time	Series
Demand_Finished	Time	Series
Evaluation_Finished	Time	Series
Backorder_Item_Finished	Time	Series
Inv_check_m	Time	Series
Inv_check_f	Time	Series
bo_check_m	Time	Series
bo_check_f	Time	Series

In discrete-event simulation, resources are the agencies used to process entities. In the supply chain simulation, transportation resources are used to move entities. In this model, the resources include steam ships, railway cars, trucks for inbound transportation, and trucks for outbound distribution to the eleven markets. Table 5 summarizes the resources in this simulation model.

Table 5: Resource Definition

Resource Name	Path	Cost (fpm)
Ship	Steam_Line	6160
Train	Rail_Way	150
Truck_T	HW_Mem_T	150
Truck_NY	HW_T_NY	150
Truck_Washington	HW_T_Washington	150
Truck_Atlanta	HW_T_Atlanta	150
Truck_Chicago	HW_T_Chicago	150
Truck_Minneapolis	HW_T_Minneapolis	150
Truck_Seattle	HW_T_Seattle	150
Truck_Denver	HW_T_Denver	150
Truck_LA	HW_T_LA	150
Truck_Phoenix	HW_T_Phoenix	150
Truck_Houston	HW_T_Houston	150
Truck_Miami	HW_T_Miami	150

The path networks in the simulation define the way of travel for entities and resources.

In the global supply chain simulation, the network is comprised of steamship lines, railways, and highways, which is summarized in Table 6. In the table, the travel time is input from an external Excel spreadsheet. Fdata[6,2] means that the number is from the cell of the sixth row and second column in the spreadsheet.

Table 6: Path Network Definition

Name	BI	Dist/Time
Steam_Line	Bi	Fdata[6,2]
Rail_Way	Bi	Fdata[8,4]
HW_Mem_T	Bi	Fdata[10,3]
HW_T_LA	Bi	Fdata[16,4]
HW_T_NY	Bi	Fdata[14,3]
HW_T_Chicago	Bi	Fdata[14,4]
HW_T_Minneapolis	Bi	Fdata[14,5]
HW_T_Seattle	Bi	Fdata[14,6]
HW_T_Denver	Bi	Fdata[16,3]
HW_T_Phoenix	Bi	Fdata[16,2]
HW_T_Houston	Bi	Fdata[16,5]
HW_T_Miami	Bi	Fdata[16,6]
HW_T_Atlanta	Bi	Fdata[18,2]
HW_T_Washington	Bi	Fdata[14,2]

Figures 5 and 6 are the layout of this simulation. In this project, GIS map is combined with the supply chain simulation. Therefore, it is easy to demonstrate the whole supply chain simulation when the program is running.

Figure 5: Overall Simulation Layout for the Basic Model

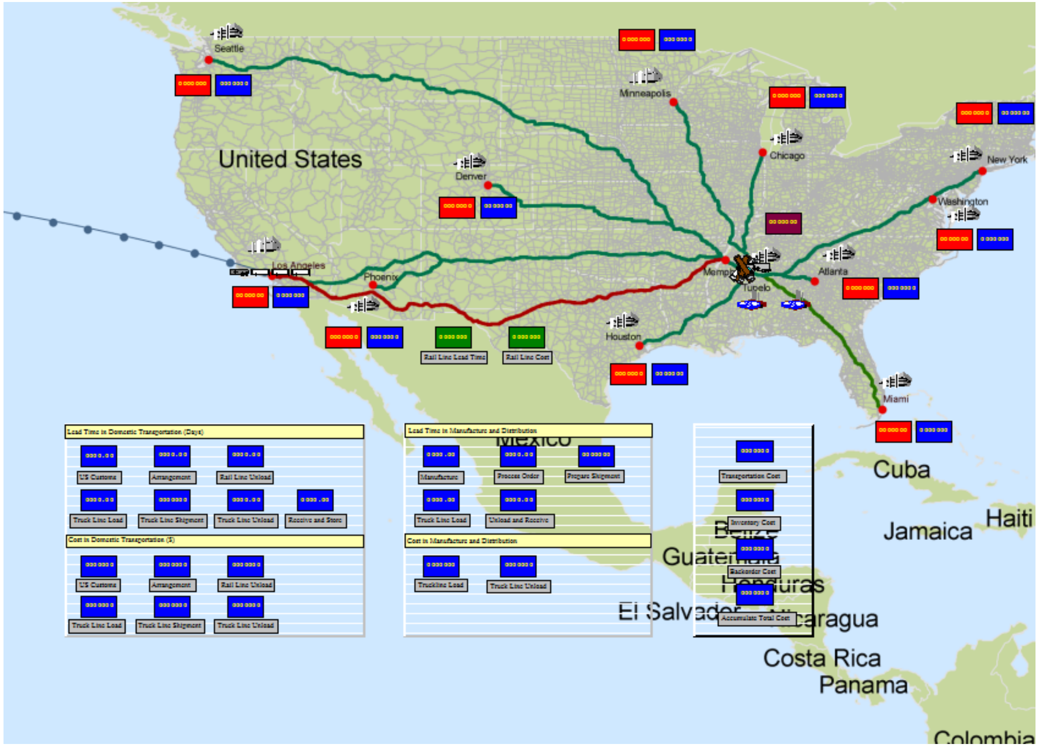

Figure 6: Simulation Layout of the Basic Model in the US

5.3 Simulation Inputs

To keep the flexibility of the simulation model, the input data file is separate from the simulation model and can be changed by users without interfering with the simulation models. The inputs data mainly include the lead times and costs for each step in the supply chain, the inventory policies, and the demand rates for both the items that require manufacturing and the finished furniture imported from overseas. The input data are organized into six tables in the input file. Table 7 below is the first input data table for lead times and inventory policies for items that require manufacturing. The first line defines the (r, q) inventory policy. In this instance, when the inventory drops to two containers (r=2), an order of two containers (q=2) is issued. The current basic simulation model assumes the initial inventory to be zero. Users can change the inventory policy by providing different values for r, q, and initial inventory. The remaining part of the table provides the lead times (in days) for each step along the supply chain, including steps of order initialization, ocean shipment, railway shipment, highway shipment to the manufacturer, manufacturing, and distributions to major markets. "RM" in the table means the import is *r*aw *m*aterial and requires manufacturing. The transportation times to major markets are estimated based on their distances from Tupelo, MS.

Table 7: Inventory Policy and Lead Time Inputs for Items Requiring Manufacturing

Inventory Policy (RM)	Reorder Point	Order Quantity	Initial Inventory		
Lead Time (Day)	2	2	0		
Order Initialization	Order Verification	Freight Pickup	Book Ship Lines	AMS Submission	Verification and Load Ship
	3	0.05	7	1	7
Steam Ship Line	Overseas Travel Time	Unload from Ship			
	17	0.05			
Railway	Customs	Railway Arrangement	Railway Travel Time	Unload from Train	
	0.05	0.05	7	0.05	
Highway	Load Truck	Highway Travel Time	Unload from Truck	Receive Goods	Manufacturing
	0.05	1	0.05	0.05	7
Distribution Within MS	Process Order	Prepare Shipment	Load Truck	Highway Travel Time	Receive Goods
	7	1	0.05	0.2	0.05
Distribution Outside MS	Washington	New York	Chicago	Minneapolis	Seattle
	2	3	2	2	4
	Phoenix	Denver	LA	Houston	Miami
	3	2	4	1	2
	Atlanta				
	1				

Table 8 is the second data input table for the cost structure of the supply chain for the items that require manufacturing. All costs are in US dollars for one container-load on the inbound side or for one truckload on the distribution side. The simulation model also considers the inventory holding cost and backorder costs. The distribution costs for one truckload to major markets are roughly estimated based on the distance provided by the GIS. Tables 9 and 10 are similar data tables to Tables 7 and 10 for the items imported as finished goods.

Table 8: Cost Structure for Items Requiring Manufacturing ($/Container)

Order Initialization	Freight Pickup	Shipment Preparation	Inventory Holding (per day)	Purchase and Manufacturing	Backorder Cost
	50	400	0.001369863	10000	100
Steam Ship Line	Overseas Shipping	Ship Unload			
	3600	50			
Railway	Customs	Arrangement	Railway Shipping	Train Unload	
	100	50	1436.4	50	
Highway Shipping	Truck Load	Highway Shipping	Truck Unload		
	50	360	50		
Distribution	Truck Load	Truck Unload			
	50	50			
	Washington	New York	Chicago	Minneapolis	Seattle
	1080	1320	840	1440	2160
	Phoenix	Denver	LA	Houston	Miami
	1800	1200	1920	720	840
	Atlanta				
	600				

Table 9: Inventory Policy and Lead Time Inputs for Imported Finished Furniture

Inventory Policy (FG)	Reorder Point	Order Quantity	Initial Inventory		
Lead Time (Day)	2	2	0		
Order Initialization	Order Verification	Freight Pickup	Book Ship Line	AMS Submission	Verification and Load Ship
	3	0.05	7	1	7
Steam Ship Line	Overseas Travel Time	Unload from Ship			
	17	0.05			
Railway	Customs	Railway Arrangement	Railway Travel Time	Unload from Train	
	0.05	0.05	7	0.05	
Highway	Load Truck	Highway Travel Time	Unload from Truck	Receive Goods	Manufacturing
	0.05	1	0.05	0.05	0
Distribution Within MS	Process Order	Prepare Shipment	Truck Load	Truck Shipment	Receive
	7	1	0.05	0.2	0.05
Distribution Outside MS	Washington	New York	Chicago	Minneapolis	Seattle
	2	3	2	2	4
	Phoenix	Denver	LA	Houston	Miami
	3	2	4	1	2
	Atlanta				
	1				

Table 10: Cost Structure for Imported Finished Furniture ($/Container)

Order Initialization	Freight Pickup	Shipment Preparation	Inventory Holding (per day)	Purchase	Backorder Cost
	50	400	0.001369863	10000	100
Steam Ship Line	Steam Line Shipping	Steam Line Unload			
	3600	50			
Railway	Customs	Arrangement	Railway Shipping	Railway Unload	
	100	50	1436.4	50	
Highway Shipping	Truckline Load	Truckline Shipping	Truckline Unload		
	50	360	50		
Distribution	Truckline Load	Truckline Unload			
	50	50			
	Washington	New York	Chicago	Minneapolis	Seattle
	1080	1320	840	1440	2160
	Phoenix	Denver	LA	Houston	Miami
	1800	1200	1920	720	840
	Atlanta				
	600				

Tables 11 and 12 are the demand rates of major markets for items requiring manufacturing and items imported as finished furniture respectively. We assume the overall demand rate is about one container per month for items requiring manufacturing and one container per month for items imported as finished furniture. The demand is then assigned to major markets proportional to their demand rates.

Table 11: Demands Rates for Items Requiring Manufacturing

Inter-arrival time	30				
Demand Rate	Washington	New York	Chicago	Minneapolis	Seattle
(Items	1	4	2	1	2
Requiring Manufacturing)	LA	Denver	Phoenix	Houston	Miami
	2	1	1	3	2
	Atlanta	Total (Base Model)			
	2	21			

Table 12: Demand Rates for Items Imported as Finished Goods

Inter-arrival time	30				
Demand Rate	Washington	New York	Chicago	Minneapolis	Seattle
(Items Imported as Finished Goods)	1	4	2	1	2
	LA	Denver	Phoenix	Houston	Miami
	2	1	1	3	2
	Atlanta	Total (Base Model)	Total (Alternative)		
	2	21	6		

For any data input tables, users can change the values based on their own supply chain's characteristics. Users do not need to interfere with the simulation model to tailor the simulation model for their own business.

5.4 Model Output

For a furniture supply chain, the major performance measures are total cost and lead times, including inbound lead time for the manufacturer and the outbound lead time for distributors/retailers at major markets. The lead time and cost at each step are displayed on the simulation model directly (as shown in Figure 7). The total cost and lead times are also displayed on the screen.

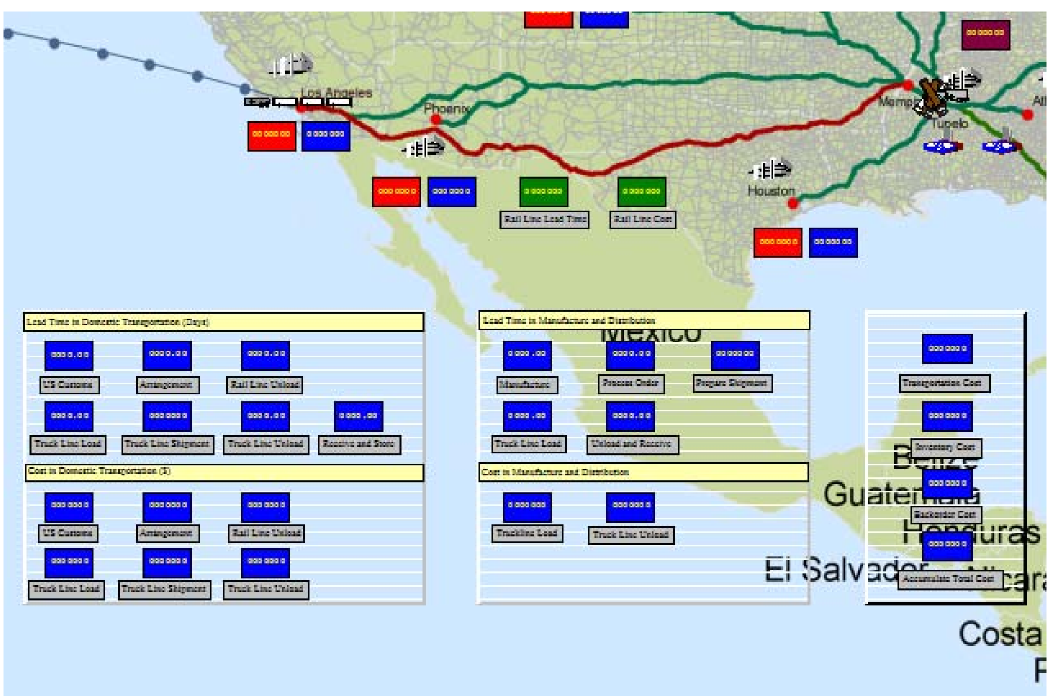

Figure 7: Output Display of the Supply Chain Simulation Model

5.5 Alternative Supply Chain Simulation

In the current supply chain, all imports are shipped to the manufacturer at first and finished furniture is shipped from the manufacturer to all major markets no matter the imports are supplies requiring manufacturing or finished furniture. DGL, the third party logistics provider mentioned in Section 4, recommends changing the supply chain for imports of finished furniture. Though small or medium–sized furniture manufacturers typically do not have warehousing capability on the west coast, third party logistics providers can offer logistics service, including warehousing and transportation, in California. This project simulates an alternative supply chain in which finished furniture is shipped to the markets of LA, Seattle, Denver, and Phoenix via trucks directly from Long Beach, CA. This alternative supply chain means an additional inventory point but can save transportation cost and lead time for the furniture company to serve major markets in the west. The simulation layout is illustrated in Figure 8. Please note that the items requiring manufacturing and items imported as finished furniture for other markets are still shipped to the manufacturer located in Mississippi. In Figure 8, highway connections are added from Long Beach, CA to Seattle, Denver, and Phoenix.

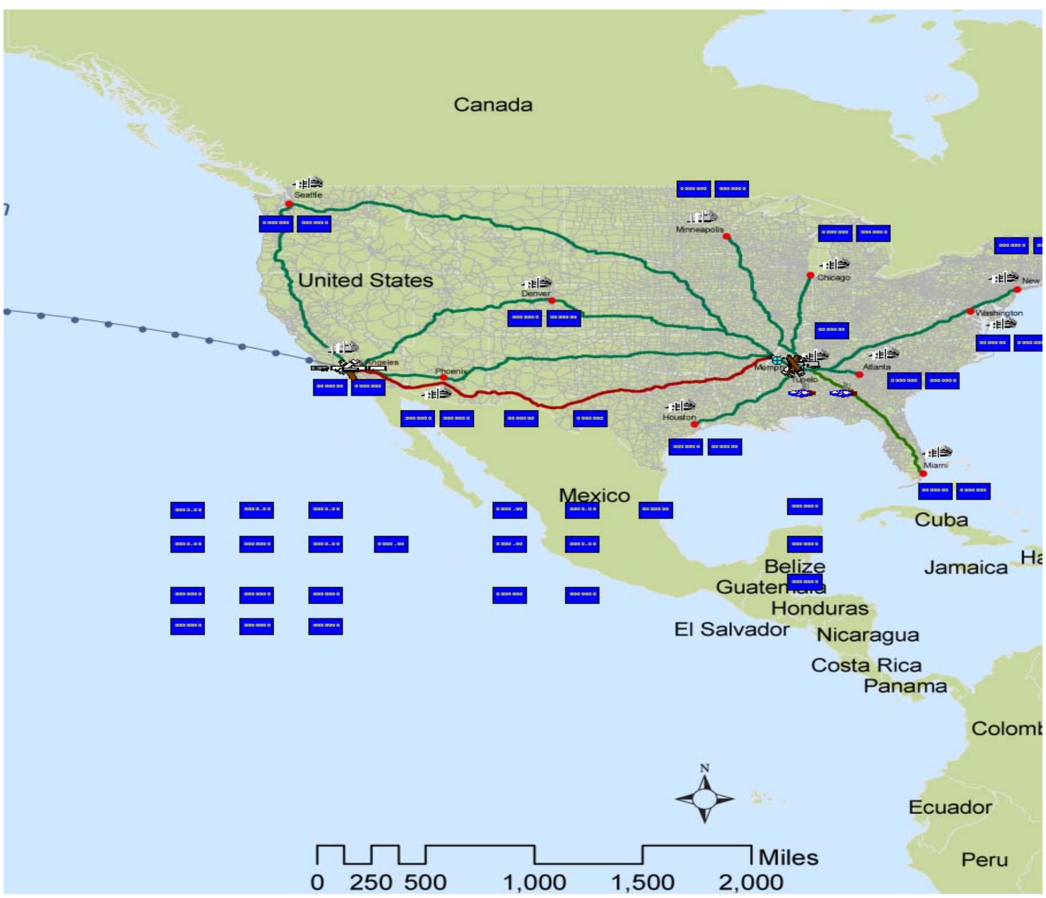

Figure 8: Simulation Layout (US Part) of the Alternative Supply Chain Simulation

6. ANALYSIS RESULTS

Numerical experiments are conducted on the simulation model studies to investigate the performance of the supply chain. The simulation model is run for 10 years to investigate the long-run performance.

6.1 Inventory Policy's Impact on Supply Chain Performance

The impact of inventory policies on the total cost for the items requiring manufacturing is shown in Table 13. In general, the inventory policy has little impact on transportation cost but can change inventory holding cost and backorder cost. Higher reorder point and/or larger order quantity typically means higher inventory cost but lower backorder cost. The highlighted row indicates the optimal inventory policies. Table 14 indicates the impact of the inventory policy on the lead times. The outbound lead time includes order processing time, waiting time if a backorder happens, and transportation time. The table shows that the reorder point has a large impact on the outbound lead time for distributors and retailers. Higher reorder point means lower backorder chance. Tables 15 and Tables 16 show the costs and lead times under different inventory policies for items imported as finished goods.

Table 13: Impact of Inventory Policy on Costs for Items Requiring Manufacturing

Reorder Point (Containers)	Order Quantity (Container)	Transportation Cost($/year)	Inventory cost ($/year)	Backorder Cost ($/year)	Other Cost ($/year)	Total Cost ($/year)
1	2	85343.2	4268.1	5880	13974.4	109465.7
1	3	85973.2	6398.3	5420	11654.9	109446.4
2	2	85093.2	6186.8	2880	13996.8	108156.8
2	3	84363.2	8059.9	1980	13908.8	108311.9
3	2	84713.2	8226.5	1520	13931.2	108390.9
3	3	85713.2	9714.9	960	13936.2	110324.3

Table 14: Impact of Inventory Policy on Lead Times
for Items Requiring Manufacturing

Reorder Point (Cont.)	Order Quantity (Cont.)	Inbound Lead Time (Days)	Outbound Lead Time for Distributors or Retailers (Days)										
			DC	New York City	Chicago	Minneapolis	Seattle	Denver	LA	Phoenix	Houston	Miami	Atlanta
1	2	43	10.5	16.3	14.5	9.8	17.8	10.9	16.6	11.3	15.2	16.8	13.4
1	3	43	11.2	11.4	10.8	11.7	12.4	11.1	16.4	11.8	12.6	13.4	10.2
2	2	43	10	14.2	10.1	9.8	13	10	14	12	15	12	7.4
2	3	43	9.9	13.3	14	11	15.2	10	12	11.7	11.3	11.4	9
3	2	43	10	11	10	9.8	12	10	12.8	11	9.6	11.4	8.8
3	3	43	10	11.6	11.8	10	12.6	10	12	11	9	13	8.7

Table 15: Impact of Inventory Policy on Costs
for Items Imported as Finished Furniture

Reorder Point (Container)	Reorder Quantity (Container)	Transportation Cost($/year)	Inventory cost ($/year)	Backorder Cost ($/year)	Other Cost ($/year)	Total Cost ($/year)
1	2	95487.8	4063.2	6740	16193.6	122484.6
1	3	93817.8	4845.5	5680	16386.5	120729.8
2	2	94377.8	5846.1	3600	16266.5	120090.4
2	3	95207.8	6859.8	2300	13332.2	117699.8
3	2	95337.8	7537.9	1020	13436.4	117332.1
3	3	93577.8	9306.9	1080	16176.3	120141

Table 16: Impact of Inventory Policy on Lead Times
for Items Imported as Finished Furniture

Reorder Point (Cont.)	Order Quantity (Cont.)	Inbound Lead Time (Days)	Outbound Lead Time for Distributors or Retailers (Days)										
			DC	New York City	Chicago	Minneapolis	Seattle	Denver	LA	Phoenix	Houston	Miami	Atlanta
1	2	43	16.2	14.8	16	10	16.7	11.2	17.9	10.7	12.6	19.9	10.2
1	3	43	11.9	14	12.8	11.4	13.9	10	13.5	12.4	14.2	11.3	10.1
2	2	43	10	13.3	12.8	10	18.1	10	13.5	11	10.2	12.8	10.9
2	3	43	9.8	12.5	12.7	10.7	12.1	10.3	11.9	11.6	12	12.8	10.1
3	2	43	10	13.4	10	9.5	14.5	10	12.3	11	8.6	12.2	9
3	3	43	9.8	11.1	12.7	10	14	10	13.2	11	9.7	10.2	9

6.2 The Benefit of the Alternative Supply Chain

As mentioned in Subsection 5.5, an alternative supply chain is simulated to demonstrate improvement opportunities for a typical furniture company in Mississippi. The following Table 17 summarizes the benefit of the alternative supply chain for different transportation costs. Since transportation cost is mainly decided by fuel prices, most transportation providers charge fuel surcharge.

Table 17: Cost Comparison between Basic Model and Alternative Supply Chain
($/year)

	Transportation Cost Changes				
	-20%	-10%	0	10%	20%
Basic Model	101080.4	110585.4	120090.4	129578	139083
Alternative Supply Chain	89800.2	98157.2	106514.2	114859	123216
Improvement ($/year)	11280.2	12428.2	13576.2	14719	15867

Table 17 shows about 10% saving in overall cost if the manufacturer adopts the alternative supply chain and utilize the service of the third party logistics providers in the west coast.

7. CONCLUSION

This project simulates a typical global supply chain for a small furniture manufacturer in Mississippi based on GIS maps. The simulation model can help furniture manufacturers better understand how their global supply chain operates, including both inbound/ outbound logistics, by a visual display. The separate input data file designed in this research allows users to input their own business data and investigate their own supply chain. The model in this research can help manufacturers identify the best inventory policy to reduce the cost and lead times. The simulation model can also be used as an educational tool to see the influence of changes of the supply chain to help the small business owners make a better decision. The simulation results suggest that the small business owners should play a more active role in their supply chain rather than just passively issue orders. Moreover, the specific simulation model allows for the small business owners to operate the system form a different perspective. For example, as mentioned in section 5.5, the project simulates an alternative supply chain to demonstrate improvement opportunities. The alternative supply chain utilizes third party logistics providers' service and distributes imported finished furniture to major markets on the west coast. The alternative can reduce the overall cost by 10%. The saving is more significant if the transportation cost rises further with fuel prices.

8. PROJECT DISSEMINATION

This project has also received an award from American Furniture Foundation. Project results have been disseminated in many forms, including conference presentations/posters and a report to American Furniture Foundation. A journal paper is under development based on the results of the project. This allowed for dissemination to both academic and practitioner communities.

Papers/Reports

· Jin, M., Cook, B., Bullington, S, Eskioglu, B. (2008). Geographic Information Systems Capability of Demonstrating the Current and Alternative Supply Chains for A Furniture Manufacturing Company, a report to American Furniture Foundation**.**

Presentations/Posters

· Li, L, Jin, L, Zhang, L. (Feb 2009). “Humanitarian Supply Chains: Do Relief Agencies Utilize Intermodal Transportation?” *MSU Transportation Workshop*, MSU.

1. Would you consider your project to be basic research, advanced research, or applied research?	**Applied Research**
2. Number of transportation research reports/papers published	**1**
3. Number of transportation research papers presented at academic/professional meetings	**1**
4. Number of students participating in transportation research projects	**1 graduate**
5. Number of transportation seminars, symposia, distance learning classes, etc. conducted for transportation professionals	**0**
6. Number of transportation professionals participating in those events	**0**

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