Limits to Growth (of a Model)

featuring

Failure Analysis and Modeling Environment (FAME)

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ABSTRACT

Networks are often modeled in discrete-event simulations to represent the physical behavior of routers, switches, packets, etc. A supply chain could similarly be modeled as a system of nodes and edges from origin to destination. When the desire is to model aggregate products (whether discrete packages or continuous flows) to examine the resilience of a network to disruptions, a system dynamics approach is adequate. In a literature search on this topic, very few models were found. This paper represents on-going work in modeling product flows through a network of nodes. It was meant to be a first principles exploration at simultaneously solving the minimum cost and maximum flow problems in the face of outages to examine alterative architectures that are more resilient for a complex real application.

BACKGROUND AND PROBLEM STATEMENT

Just as system dynamics is a broadly applicable discipline that can be used to solve a plethora of problems, a network model such as this can likewise be broadly applied. Whether our interest is in evaluating supply chains or intelligence chains, the basics remain the same. We need to get supply from the origin(s) through a network to satisfy demand at the destination(s).

The impetus for this model arose from a basic Excel allocation and capacity management model to assign a number of tasks/problems to a number of collection assets through a network of transport assets to a number of destinations using matrix math. A few major differences between that model and the one being presented here are:

- Besides varying the numbers and assignments in that model, it lacked the element of time (e.g. arrivals, volume, bottlenecks, etc.).
- While it captured cascading nodal allocation/assignment by priority, it lacked nodal degradation and restoration over time.
- While it optimized allocation of capacity, it lacked the ability to plot benefit (e.g. throughput) and cost (e.g. latency) as a function of other occurrences (e.g. outages).

A useful analogy for what we are trying to achieve here would be advanced planning & scheduling in supply chains. Given a supply/demand forecast and a set of resources to produce a line of products, a planner would take the following basic steps:

1) Develop a digital twin that optimizes the supply chain (min cost + max deliveries)
2) Forecast demand at destinations and translate into required supply at origins
3) Generate a production and distribution schedule to satisfy demand
4) When unforeseen outages occur, generate a new schedule
   a. If partial outage (e.g. slowdown on machine X), then fix the problem
   b. If complete outage (e.g. bridge closed for 6 months), then re-plan

Either way, a planner would need to re-run the original model to route around the problem and retrieve some percentage of lost capacity while dealing with the problem. This model is meant to explore a dynamic re-assignment and optimization capability for when unexpected outages happen in a network. Preferably, we could design the network to be more resilient.

The Data

Model data is contained in four matrices: a) Origin-to-Destination Allocation, b) Origin-to-Transport Allocation, c) Transport-to-Transport Allocation, and d) Transport-to-Destination Allocation. Entries in all matrices can indicate on/off, weights, costs, priorities, etc. Here we are just modeling on/off.

a) Origin-to-Destination Allocation

Given we have three products (P) generated at five origins (O) assigned to five destinations (D), we can represent this allocation with a single matrix showing the amount produced at the origins and the destinations to which they are assigned. Table 1 shows the assignment of Products from Origin (supply) to Destination (demand).

Origin	Product	Destination					
		D1	D2	D3	D4	D5	Sum
O1	P1	20	0	0	0	0	20
O2	P1	0	0	0	0	0	0
O3	P1	40	0	0	0	0	40
O4	P1	0	0	0	0	0	0
O5	P1	10	0	0	0	0	10
O1	P2	0	0	20	0	0	20
O2	P2	0	0	0	0	0	0
O3	P2	0	0	20	0	0	20
O4	P2	0	0	0	0	0	0
O5	P2	0	0	40	0	0	40
O1	P3	0	0	0	0	60	60
O2	P3	0	0	0	0	0	0
O3	P3	0	0	0	0	40	40
O4	P3	0	0	0	0	0	0
O5	P3	0	0	0	0	50	50
	Sum	70	0	80	0	150	300

Table 1: Origin/Product-to-Destination Assignment

b) Origin-to-Transport and d) Transport-to-Destination Allocation

cTable 2 shows the entry point of the origins into one or more of the Transport nodes (T). Table 3 shows the exit point out of the network to the destinations. These can be one-to-one, many-to-one, one-to-many, or many-to-many assignments.

Origin	Transport									
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
O1	1	0	0	0	0	0	0	0	0	0
O2	0	0	0	0	0	0	0	0	0	0
O3	0	1	0	0	0	0	0	0	0	0
O4	0	0	0	0	0	0	0	0	0	0
O5	0	0	1	0	0	0	0	0	0	0

Table 2: Origin-to-Transport Start Point

Transport	Destination				
	D1	D2	D3	D4	D5
T1	0	1	0	0	0
T2	0	0	0	0	1
T3	0	0	1	0	0
T4	0	0	0	0	1
T5	0	0	0	1	0
T6	0	0	1	0	0
T7	0	1	0	0	0
T8	1	0	0	0	0
T9	0	0	0	1	0
T10	1	0	0	0	0

Table 3: Transport-to-Destination Exit Point

c) Transport-to-Transport Allocation

Table 4 shows the network paths from/to (or to/from) each Transport node (T). Normally, a directed graph (or upper triangular matrix) is used to represent uni-directional flow, but in the case where products can flow both ways (e.g. electrons, satellite data, etc.) and the shortest path may be from right-to-left or east-to-west we would need a undirected graph (or upper/lower matrix) to capture bi-directional flows as shown in Table 4.

Transport (From)		Transport (To)									
		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
	T1	0	1	0	0	0	0	0	0	0	1
	T2	1	0	1	0	0	0	0	0	0	0
	T3	0	1	0	1	0	0	0	0	0	0
	T4	0	0	1	0	1	0	0	0	0	0
	T5	0	0	0	1	0	1	0	0	0	0
	T6	0	0	0	0	1	0	1	0	0	0
	T7	0	0	0	0	0	1	0	1	0	0
	T8	0	0	0	0	0	0	1	0	1	0
	T9	0	0	0	0	0	0	0	1	0	1
	T10	1	0	0	0	0	0	0	0	1	0

Table 4: Transport-to-Transport Network

The Model

There are basically 2 modules in this model: a) Main Stock/Flow and b) Failure Modes.

a) Main Stock/Flow Module

The module in Figure 1 has 4 stocks: Origin, Transport, Lost, and Destination. The Origin stock has an initial supply as well as a supply [pulse] train to represent future flows. The Initial Supply is subscripted as Origin[P,O,D] to represent each product assignment from Origin-to-Destination using the numbers from Table 1. This is important unless the product is well-mixed and homogeneous (e.g. electrons) where origin and destination assignments don't matter. For this model, it does matter.

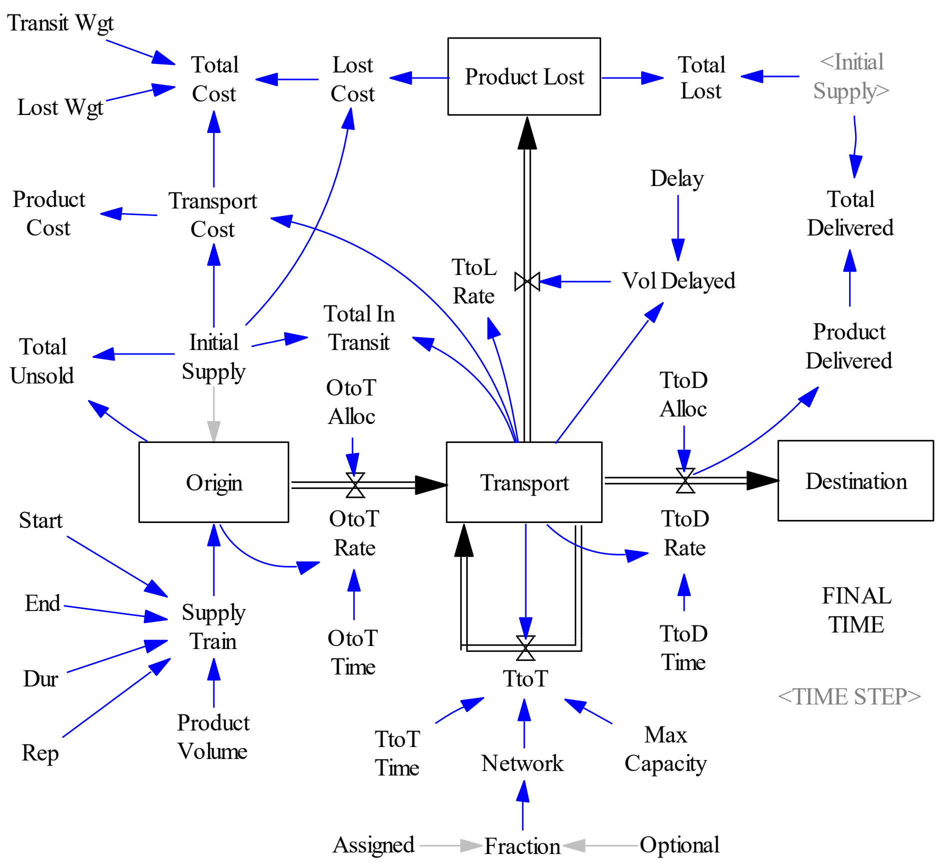


Figure 1: Main Stock/Flow Module

The OtoT Rate[P,O,T,D] flow controls the transfer of the Origin stock into the Transport stock with allocation determined by OtoT Alloc[O,T] using the numbers from Table 2. The TtoT Rate[P,O,T,D] flow controls the transfer of products from/to (or to/from) in the Transport stock with allocation determined by Network from the numbers in Table 4. The TtoD Rate flow controls the transfer of products from the Transport stock to the Destination stock with allocation determined by TtoD Alloc[T,D] from the numbers in Table 3.

If the product at each Transport node remains constant relative to Vol Delayed for more than Delay time steps, the amount at that Transport node is assumed to be stalled and is drained immediately into the Product Lost stock by the TtoL Rate[P,O,T,D] flow. This is done in a single time step and could represent a reverse supply chain back to the Origin until there is an available path for that product to flow through.

b) Failure Modes Module

Node failures can be modeled by combinations of binary (0, 1) or stochastic (0-1) variables and as constant or at some frequency over time. To consider all combinations (e.g. Latin Grid) requires 2^n where n = number of nodes. To consider stochastic options we could use Monte Carlo (e.g. multi-variate) with sampling distributions. The probability of being in an alive, failed, or restored state over time is similar to a SIR model in that nodes can move from one state to another over time based on Frequency and Duration.

Figure 2 shows the mechanism for enabling failures in Origin, Transport, or Destination. Failures can have different probabilities and profiles. They can be independently selected and be constant (i.e. Initial) or at some frequency and duration of time steps. The distributions used in the "Fails" variables below are Binomial with 0-1 probability with 1 draw and 0 shift or stretch.

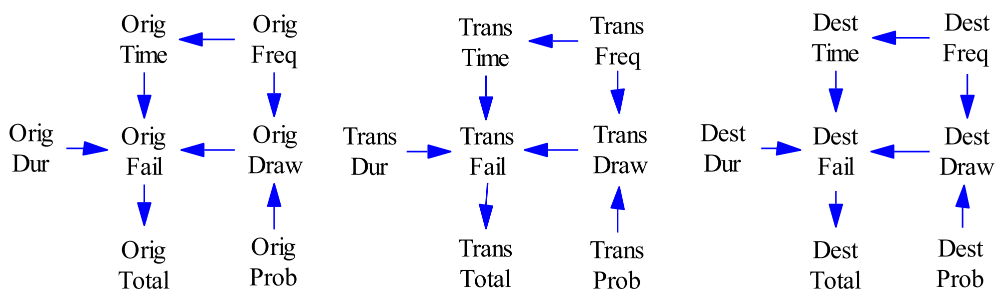


Figure 2: Failure Modes Module

TRADE SPACE METRICS

Two high-level metrics to consider for trades are a) performance and b) cost. Both will be affected in different ways by the failure modes and resiliency of the architecture to resist and/or recover from outages.

a) Performance

Performance can be calculated as volume over time or throughput (e.g. Gbps). The Total Delivered shown in Figure 3 depends on two things: 1) fastest path or 2) shortest path. Time in transit = distance / rate. If the shortest path is congested, then it may not be the fastest path and a longer path at a greater rate may be the best performing path. Delivering more quantity in a shorter time results in higher performance and happier customers.

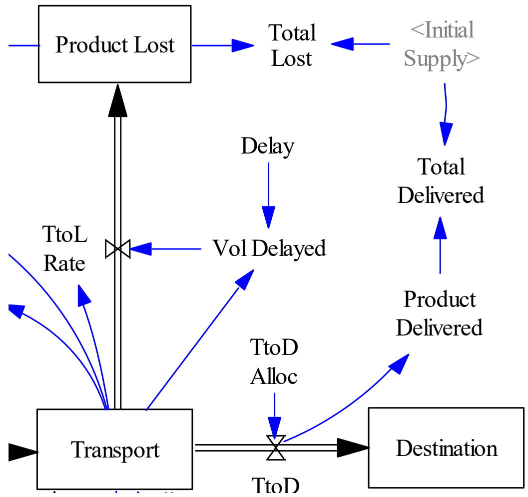


Figure 3: Performance Components

b) Cost

Cost can be calculated as two things: 1) delays in transit and 2) lost product. If products are shipped and there is no path to a destination for some duration, they are stalled in transit and accumulate more cost than they're worth. In Figure 4, Transport Cost is the ratio of the time averaged sum of the Transport stock to the Initial Supply. If that ratio > 1, inventory costs accumulate and/or customers begin to go elsewhere. If the product is non-perishable, it can be retrieved and re-shipped. If it is perishable (e.g. produce, data, etc.) it becomes a sunk cost and is lost for good.

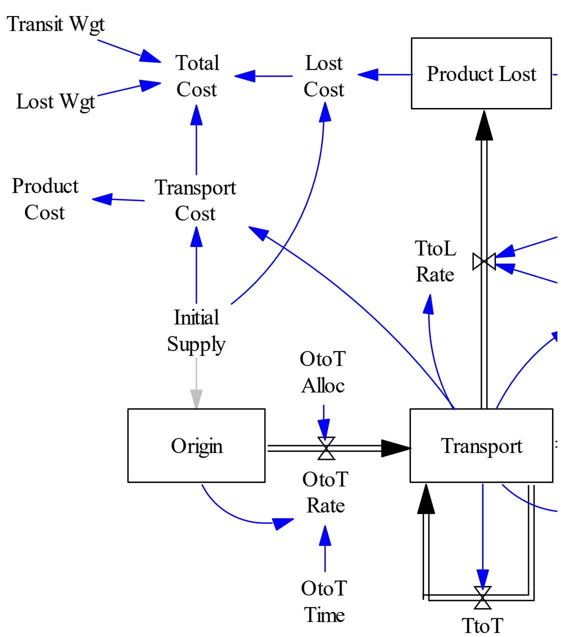


Figure 4: Cost Components

Trade Space Analysis

Two ways we can examine the trade space are a) Sensitivity and b) Optimization.

a) Sensitivity

Sensitivity can examine different kinds of node failures, whether one subscripted variable at a time or combinations of multiple variables at different levels. A vector search using Latin Grid will result in a full factorial where the number of simulations can add up quickly, so a modeler must be conscious of the number of combinations being considered before kicking off a Sensitivity Analysis. This pitfall is discussed in greater depth in the section Limits to Growth (of a Model), ergo the title of the paper.

In example one, if we vary only Trans Prob[T] for each of the 10 Transport nodes as binary (on/off) in Figure 5 and hold Trans Freq constant, we will need 2^10 = 1024 simulations. The resulting values for Total Delivered and Total Cost are shown in Figures 6 and 7 as "draw-down" curves when plotted against the number of failed nodes. The term draw-down means how fast performance falls and cost rises from failed nodes. The green line/dots in each plot show the best cases, whereas the red line/dots show the worst cases. There are many intermediate cases but these are left out to emphasize the boundaries of the trade space. The shape of the Total Cost curve will vary based on the values for Transport Wgt and Lost Wgt as well as entry points in Table 2.

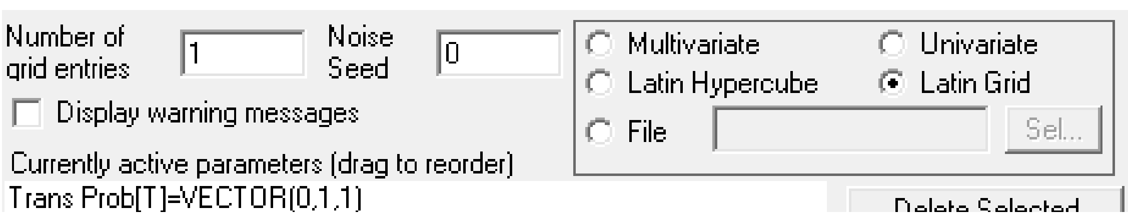


Figure 5: Sensitivity Runs Example 1

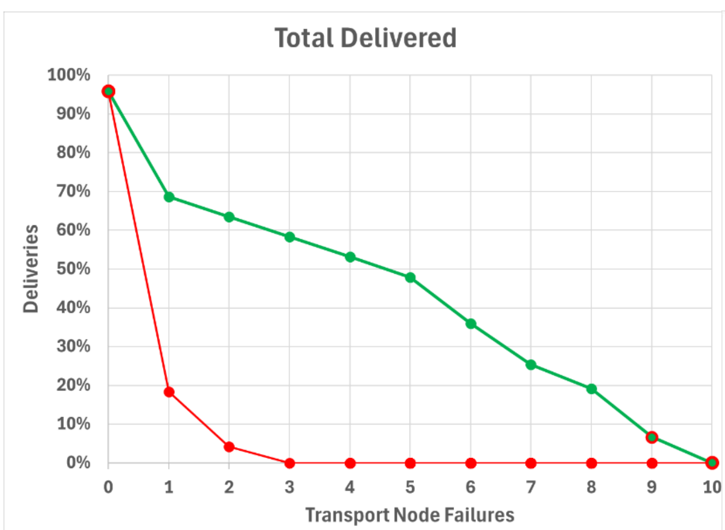


Figure 6: Deliveries vs Transport Node Failures

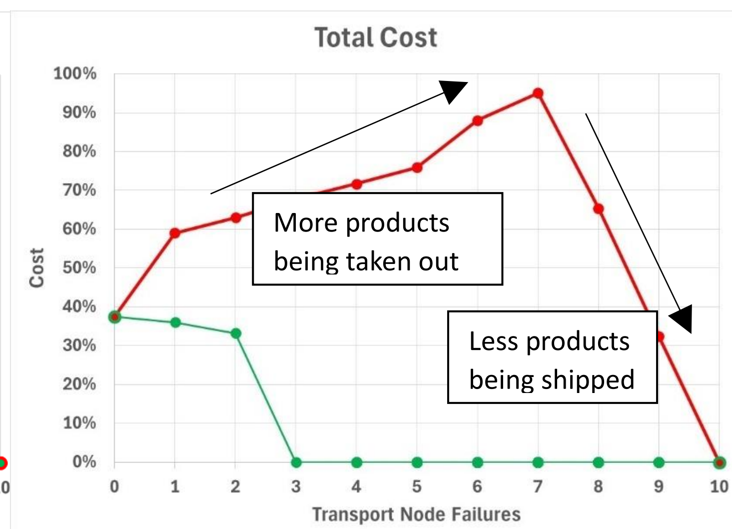


Figure 7: Cost vs Transport Node Failures

In example two, if we varied Trans Dur from high-to-low (2,18,2), Trans Freq from high-to-low (4,16,4), Trans Prob from low-to-high (0.1,0.9,0.1), and Delay from short-to-long (10,90,40) at the same time as in Figure 8, we would need 972 simulations. The resulting values for Total Delivered and Total Cost are shown in Figures 9 and 10 as dot-plots of Tran Prob vs Trans Dur where the size of the dots represent the magnitude of delivered (larger is better) and cost (smaller is better). Intuition says the worst should be when Trans Prob and Tran Dur are both high but the opposite when both are low. The charts generally agree with this.

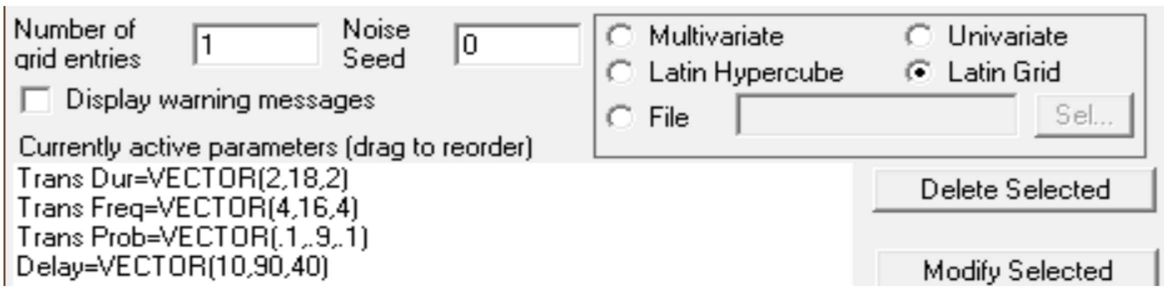


Figure 8: Sensitivity Runs Example 2

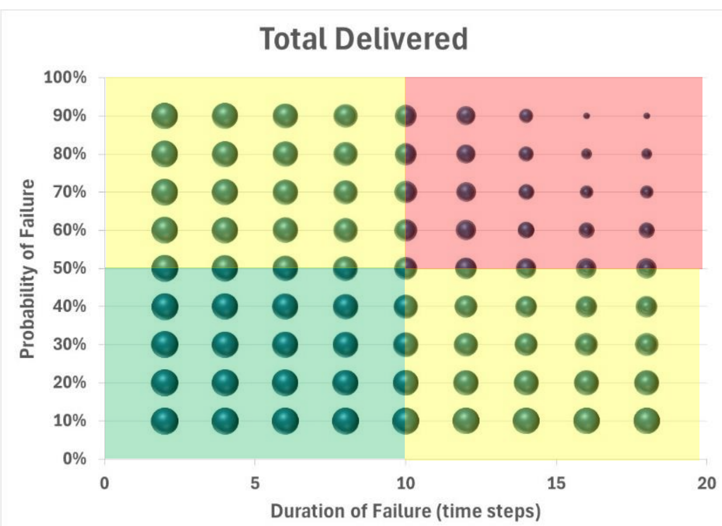


Figure 9: Delivered for Fail Prob vs Fail Dur

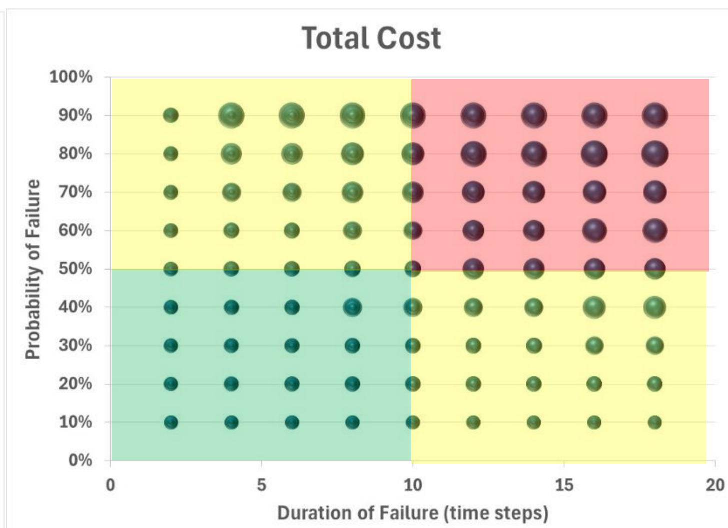


Figure 10: Cost for Fail Prob vs Fail Dur

b) Optimization

Figure 11 shows the weighted Payoff function for the optimizer made up of Total Cost and Total Delivered. The (-1) coefficient on Total Cost indicates that lower cost is better and the (+2) coefficient on Total Delivered indicates that greater deliveries are better as well as being 2x as

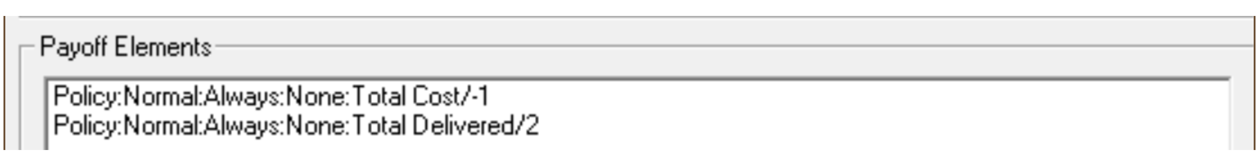


Figure 11: Optimization Run Payoff Function

important as minimizing cost. Vensim offers 2 optimization methods in the Optimization control panel: 1) Powell and 2) Monte Carlo Markov Chain (MCMC). Only Powell is examined in this paper.

Additionally, Vensim offers two "on-the-fly" techniques that optimize while in Synthesim Mode but require a bit more coding while increasing simulation time significantly (without the option of halting a run).: 1) Find Zero (or Simultaneous) and 2) LPSolve. These options may be explored in future versions of this model.

Figure 12 shows the Optimizer setup using the Optional[T,T] variable double-subscripted for each from/to (or to/from) Transport node pair. Table 5 describes 6 optimization runs conducted for a high Probability of Failure (0.8) and low (20) to high (2) Frequency of Failure. Three runs were done for each combination: 1) Non-Optimal (base Synthesim run), Binary (0/1 only), and Fraction (0-1). Figure 13 shows the resulting Percentages of Total Delivered and Total Cost. The Fraction runs represent the division of products at certain nodes to route around outages, under the assumption products can be divided. If this is not the case, then the Binary runs would be a constraint.

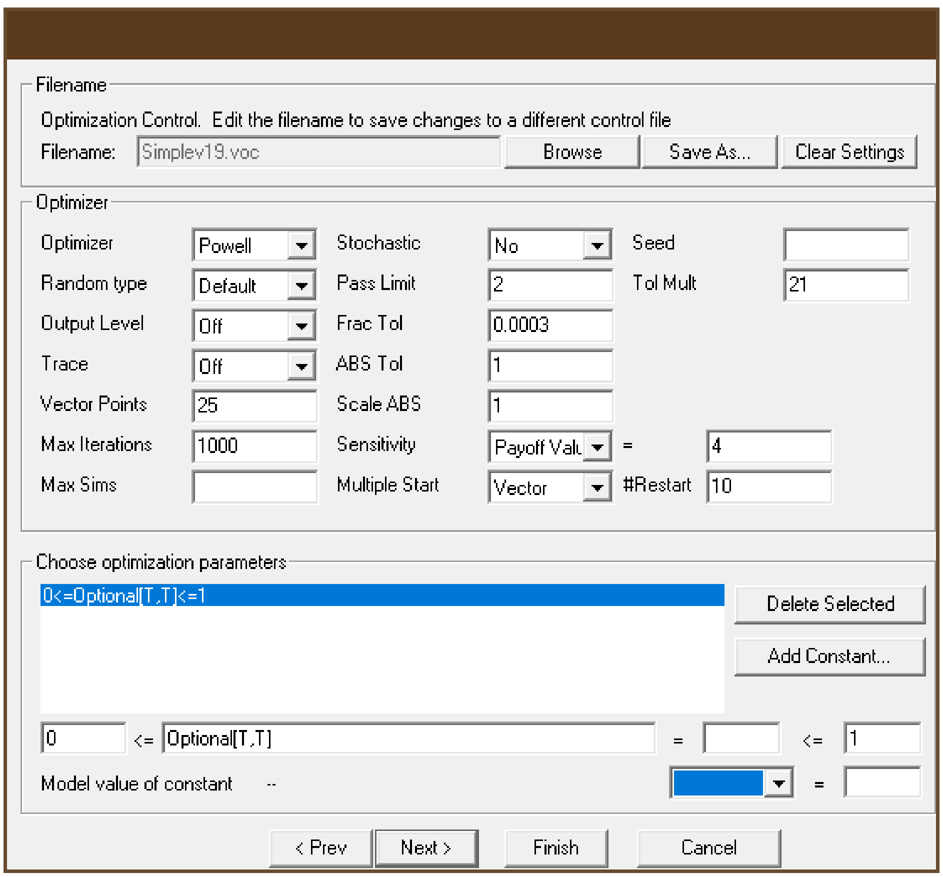


Figure 12: Optimization Run Parameters

Probability of Failure	Frequency of Failure	Optimality	Total Delivered	Total Cost
High (0.8)	Low (20)	Non-Optimal	23%	59%
		Binary	39%	37%
		Fraction	57%	26%
	High (2)	Non-Optimal	61%	48%
		Binary	68%	45%
		Fraction	75%	44%

Table 5: Results from Optimization Runs

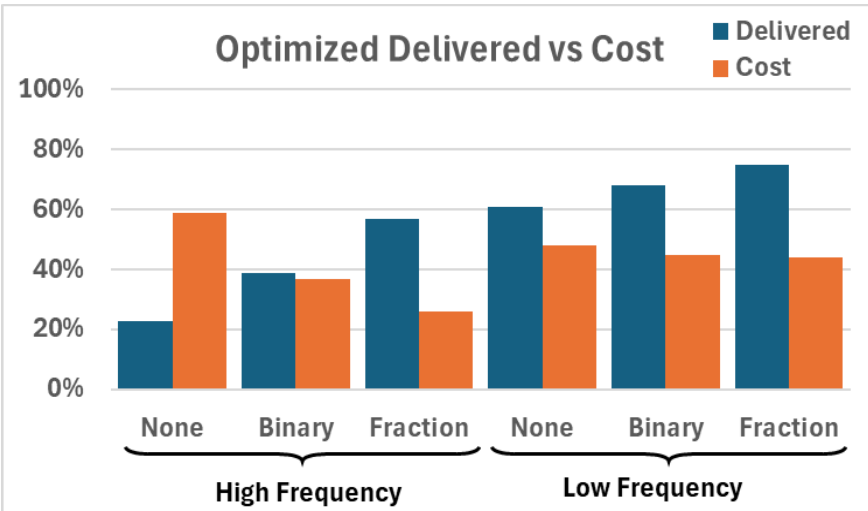
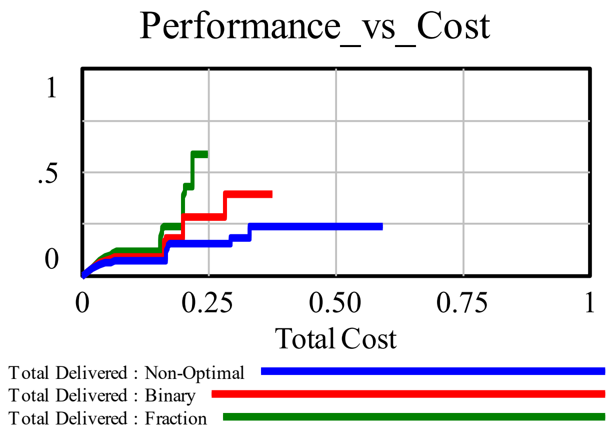


Figure 13: Chart of Results from Optimization Runs

Figures 14 and 15 show plots of Performance vs Cost and the optimal node settings to simultaneously achieve minimum cost and maximum flow for the 4 optimization runs. Figure 14 shows the optimizer results for the Low Frequency case and Figure 15 shows the optimizer results for the High Frequency case. The blue lines are from simple Synthesim runs using the base Non-Optimal node settings. The red lines are from optimizer runs with a Binary constraint. The green lines are from optimizer runs with Fractions allowed. We can observe that performance and cost are both improved with binary values but most improved with fractional values. This is presumably because the flows are being "throttled" to direct product on a more efficient (shorter or faster) route.

More deliveries are made sooner at a *lower* cost for low Frequency/Duration whereas less deliveries are made later at *higher* cost with high Frequency/Duration. Delivery/Cost perform better with lower Frequency/Duration and when network has time to "heal" to pass products on by eventually finding a path to get through whereas with longer term outages, the products get "stuck" and removed from the system based on the Delay variable.



Non-Optimal

Transport (From) \ Transport (To)	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
T1	0	1	0	0	0	0	0	0	0	1
T2	1	0	1	0	0	0	0	0	0	0
T3	0	1	0	1	0	0	0	0	0	0
T4	0	0	1	0	1	0	0	0	0	0
T5	0	0	0	1	0	1	0	0	0	0
T6	0	0	0	0	1	0	1	0	0	0
T7	0	0	0	0	0	1	0	1	0	0
T8	0	0	0	0	0	0	1	0	1	0
T9	0	0	0	0	0	0	0	1	0	1
T10	1	0	0	0	0	0	0	0	1	0

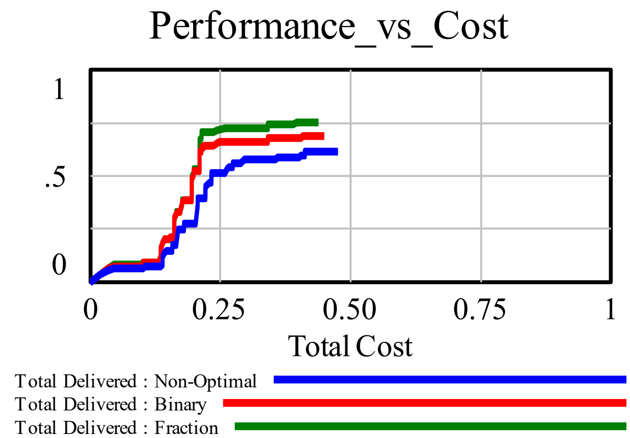
Binary

Transport (From) \ Transport (To)	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
T1	0	0	0	0	0	0	0	0	0	1
T2	1	0	0	0	0	0	0	0	0	0
T3	0	0	0	1	0	0	0	0	0	0
T4	0	0	0	0	1	0	0	0	0	0
T5	0	0	0	1	0	1	0	0	0	0
T6	0	0	0	0	1	0	1	0	0	0
T7	0	0	0	0	0	1	0	1	0	0
T8	0	0	0	0	0	0	1	0	1	0
T9	0	0	0	0	0	0	0	1	0	1
T10	1	0	0	0	0	0	0	0	1	0

Fraction

Transport (From) \ Transport (To)	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
T1	0	0	0	0	0	0	0	0	0	1
T2	0.19	0	0	0	0	0	0	0	0	0
T3	0	0	0	0.25	0	0	0	0	0	0
T4	0	0	0	0	0	0	0	0	0	0
T5	0	0	0	1	0	1	0	0	0	0
T6	0	0	0	0	1	0	1	0	0	0
T7	0	0	0	0	0	1	0	1	0	0
T8	0	0	0	0	0	0	1	0	1	0
T9	0	0	0	0	0	0	0	1	0	1
T10	0	0	0	0	0	0	0	0	0	0

Figure 14: Low Frequency of Failure



Non-Optimal

Transport (From) \ Transport (To)	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
T1	0	1	0	0	0	0	0	0	0	1
T2	1	0	1	0	0	0	0	0	0	0
T3	0	1	0	1	0	0	0	0	0	0
T4	0	0	1	0	1	0	0	0	0	0
T5	0	0	0	1	0	1	0	0	0	0
T6	0	0	0	0	1	0	1	0	0	0
T7	0	0	0	0	0	1	0	1	0	0
T8	0	0	0	0	0	0	1	0	1	0
T9	0	0	0	0	0	0	0	1	0	1
T10	1	0	0	0	0	0	0	0	1	0

Binary

Transport (From) \ Transport (To)	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
T1	0	1	0	0	0	0	0	0	0	1
T2	0	0	1	0	0	0	0	0	0	0
T3	0	1	0	0	0	0	0	0	0	0
T4	0	0	1	0	1	0	0	0	0	0
T5	0	0	0	1	0	1	0	0	0	0
T6	0	0	0	0	1	0	1	0	0	0
T7	0	0	0	0	0	1	0	1	0	0
T8	0	0	0	0	0	0	1	0	1	0
T9	0	0	0	0	0	0	0	1	0	1
T10	1	0	0	0	0	0	0	0	1	0

Fraction

Transport (From) \ Transport (To)	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
T1	0	1	0	0	0	0	0	0	0	0
T2	0	0	0.92	0	0	0	0	0	0	0
T3	0	1	0	0	0	0	0	0	0	0
T4	0	0	1	0	1	0	0	0	0	0
T5	0	0	0	1	0	1	0	0	0	0
T6	0	0	0	0	1	0	1	0	0	0
T7	0	0	0	0	0	1	0	1	0	0
T8	0	0	0	0	0	0	1	0	1	0
T9	0	0	0	0	0	0	0	1	0	1
T10	1	0	0	0	0	0	0	0	1	0

Figure 15: High Frequency of Failure

LIMITS TO GROWTH (OF A MODEL)

The limitation with a network nodal model such as FAME is in how many nodes can be considered for outages. Herein lies the limits to growth of a model. At somewhere between 30 and 50 nodes to consider "failed" (0) or "not-failed" (1), we hit an asymptote where the problem becomes un-solvable. For example, at a speed of 7M simulations/day:

- 2^10 = 1,024 (a few minutes)
- 2^20 = 1,048,576 (4 hrs)
- 2^30 = 1,073,741,824 (5 months)
- 2^40 = 1.01e^12 (39 years)
- 2^50 = 1.13^15 (the age of the universe in minutes)

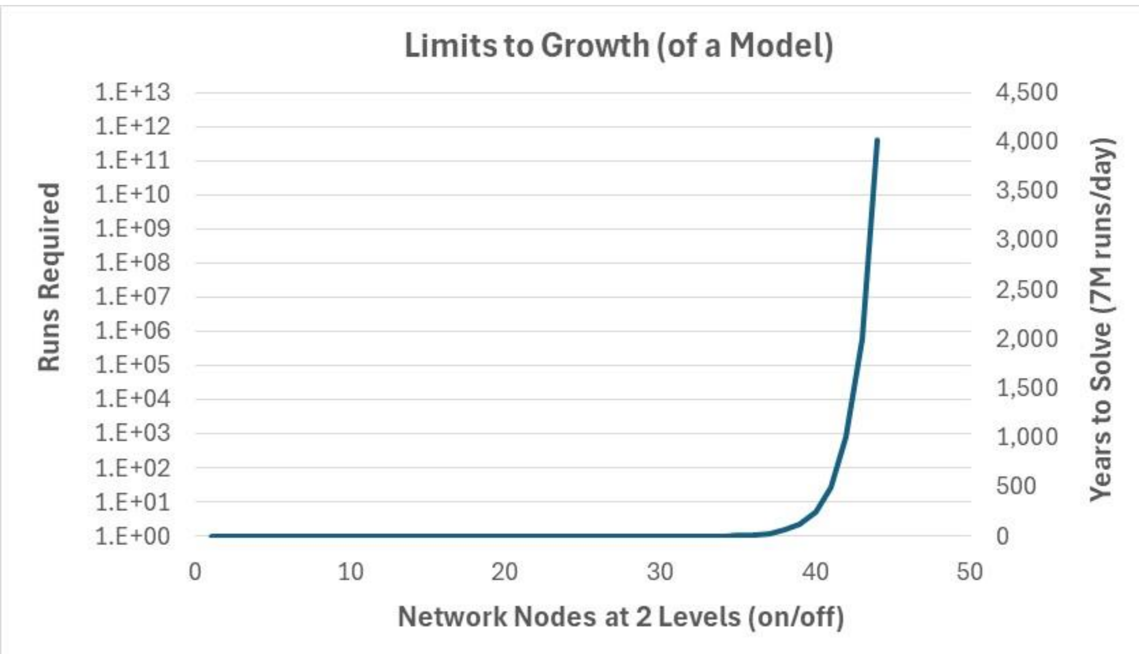


Figure 16: The Power of Exponential

In a larger model, the exponential growth of solution time requires careful selection of nodes to fail. This can be accomplished in several ways which will be examined in future versions:

- geographic isolation (likelihood of outages)
- design of experiments (trade space bounds)
- carrying capacity (node utilization)
- alternate paths (backup capacity)
- stochastics (monte carlo)

The isolation and/or buffering of most probable failure modes is part of the ongoing work and implementation for this model. It is critical to anticipate what nodes are most vulnerable to failure because of their location, workload, environment, etc. and buffer them appropriately (see Appendix A on Theory of Constraints).

CONCLUSIONS

This paper has presented an initial supply chain model representing a network of nodes from origin-to-transport-to-destination to examine resilience to outages resulting in delays or lost products. We have shown how to use Sensitivity runs to analyze the trade space by combining node outages and measuring the resulting performance (deliveries) vs. cost (delays/lost products). We have also shown how to use Optimization runs to find a minimum cost or maximum flow path in the face of outages both in terms of probability and frequency.

While a model like this cannot predict exactly where outages will occur, we can make educated guesses what nodes to examine for failure to manage solution time. The resilience lessons learned from a model like this are in how to manage capacity, "heal" the network, and where to put buffers in order to safeguard the network from unexpected outages. We often hear that the path is more important than the destination and this model encapsulates that saying by showing there can be many paths for many products from many origins to many destinations…forward and backward. It is not only important to keep track of them along the route to make sure they get where they need to go (like having an IP address) but to route them most effectively and efficiently.

FUTURE WORK

This work represents 4 months of exploration and is only a "toy" model that was kept simple on purpose to explore model behavior before applying it to a real-world problem with more nodes, connections, capacities, rules, priorities, customer preferences, etc. While this model considered multiple products assigned to origins/destinations it assumed continuous flows whereas discrete products would need queues, batches, priorities, etc. to represent non-divisible items (e.g. pallets). There are many applications for a model such as this but some would perhaps require a bit more tweaking. There is also one very important thing to consider for a specific application.

The nodes and connections in this model were assumed to be statically located and always available as in a terrestrial network. But what if the nodes were moving at 17,000 mph and their connections, capacities, locations, etc. were constantly changing? In this case, we would need to represent the physical dynamics and present the availability intervals to the model. One could imagine the data matrices as "blinking" on/off as their connections were made and broken perhaps for only minutes at a time. Data would also travel between nodes with almost no delay (speed of light) but could still be measured in milliseconds across an entire strand. The author leaves it up to the reader to guess the inferred application.

Appendix A

The Theory of Constraints

In Eliyahu Goldratt's book on The Theory of Constraint called "The Goal", drum-buffer-rope refers to a production management strategy where the "drum" represents the bottleneck in a process, the "buffer" is a safety stock for the bottleneck to make sure it remains fully utilized or has no outages, and the "rope" is the signal to pull work through the system (as opposed to pushing work into the system) at the pace of the bottleneck. The "goal" is to optimize the system by achieving maximum throughput by focusing on the constraint (the drum) while at the same time minimizing cost (e.g. inventory, lost business, etc). In reality, bottlenecks move around like the "bump in a rug" problem and the system must be reoptimized from time to time.

A model such as FAME can be used to solve a dynamic problem like this by simulating the randomness of node failures whether from the supply side, demand side, or inside the network.

Appendix B

Model Formulation

```
Assigned[X,Y] = GET XLS CONSTANTS('?Data', 'Simple', 'Network')
        ~ Dmnl ~ |

D : (D1-D5) ~  ~ |

Delay = 100
        ~ Day [0,200,10] ~ |

Dest : (D1-D5) ~  ~ |

Dest Draw[D] = SAMPLE IF TRUE( MODULO ( Time , Dest Freq ) = 0, RANDOM BINOMIAL ( 0, \
                1, 1 - Dest Prob , 1, 0, 1, 0) , 1) ~  ~ |

Dest Dur = 2
        ~  [0,20,1] ~ |

Dest Fail[D] = IF THEN ELSE ( Dest Draw[D] = 0, ( 1 - PULSE ( Dest Time , Dest Dur ) \
                ) , 1)
        ~ Dmnl ~ |

Dest Freq = 0
        ~ Day [0,20,1] ~ |

Dest Prob = 0
        ~ Dmnl [0,1,0.1] ~ |

Dest Time = SAMPLE IF TRUE( MODULO ( Time , Dest Freq ) = 0, Time , 0) ~  ~ |

Dest Total = SUM ( Dest Fail[D!] )
        ~ Dmnl ~
        ~ :SUPPLEMENTARY
 |

Destination[D] = INTEG( SUM ( TtoD Rate[P!,O!,T!,D] ) , 0)
        ~ Widgets ~
        ~ :SUPPLEMENTARY
 |
```

```
Dur = 1
	~ Day [1,10,1] ~ |

End = 200
	~ Day [0,200,10] ~ |

Fraction[X,Y] = INITIAL( ( Assigned[X,Y] * Optional[X,Y] ) )
	~ Dmnl ~ |

Initial Supply[P1,O,D] = GET XLS CONSTANTS('?Data', 'Simple', 'Product1') ~~|
Initial Supply[P2,O,D] = GET XLS CONSTANTS('?Data', 'Simple', 'Product2') ~~|
Initial Supply[P3,O,D] = GET XLS CONSTANTS('?Data', 'Simple', 'Product3')
	~ Widgets ~ |

Lost Cost[P] = ZIDZ ( Product Lost[P] , SUM ( Initial Supply[P,O!,D!] ) ) / 3
	~ Dmnl ~ |

Lost Wgt = 1 - Transport Wgt
	~ Dmnl [0,1,0.1] ~ |

Max Capacity = 100
	~ Widgets [0,100,10] ~ |

Network[X,Y] = Fraction[X,Y] * Trans Fail[X]
	~ Dmnl ~ |

O : (O1-O5) ~  ~ |

Optional[X,Y] = 1
	~ Dmnl
	~ Opt[X,Y] |

Orig Draw[O] = SAMPLE IF TRUE( MODULO ( Time , Orig Freq ) = 0, RANDOM BINOMIAL ( 0, \
		1, 1 - Orig Prob , 1, 0, 1, 0) , 1) ~  ~ |

Orig Dur = 2
	~  [0,20,1] ~ |

Orig Fail[O] = IF THEN ELSE ( Orig Draw[O] = 0, ( 1 - PULSE ( Orig Time , Orig Dur ) \
		) , 1)
	~ Dmnl ~ |

Orig Freq = 0
```

```
	~ Day [0,20,1] ~ |

Orig Prob = 0
	~ Dmnl [0,1,0.1] ~ |

Orig Time = SAMPLE IF TRUE( MODULO ( Time , Orig Freq ) = 0, Time , 0) ~  ~ |

Orig Total = SUM ( Orig Fail[O!] )
	~ Dmnl ~
	~ :SUPPLEMENTARY
 |

Origin[P,O,D] = INTEG( Supply Train[P] - SUM ( OtoT Rate[P,O,T!,D] ) , Initial Supply\
		[P,O,D] )
	~ Widgets ~ |

OtoT Alloc[O,T] = GET XLS CONSTANTS('?Data', 'Simple', 'OtoT')
	~ Dmnl [10,100,10] ~ |

OtoT Rate[P,O,T,D] = MAX ( 0, OtoT Alloc[O,T] * Trans Fail[T] * Orig Fail[O] * Origin\
		[P,O,D] ) / OtoT Time
	~ Widgets/Day ~ |

OtoT Time = 1
	~ Day [1,10,1] ~ |

P : (P1-P3) ~  ~ |

Product Delivered[P] = INTEG( SUM ( TtoD Rate[P,O!,T!,D!] ) , 0)
	~ Widgets ~ |

Product Lost[P] = INTEG( SUM ( TtoL Rate[P,O!,T!,D!] ) , 0)
	~ Widgets ~ |

Product Volume[P] = 0
	~ Widgets/Day [0,100,10]
	~ 10,20,30 |

Rep = 5
	~ Day [1,10,1] ~ |

Start = 0
	~ Day [0,200,10] ~ |
```

```
Supply Train[P] = PULSE TRAIN ( Start , Dur , Rep , End ) * Product Volume[P]
	~ Widgets/Day ~ |

T : (T1-T10) ~  ~ |

Total Cost = SUM ( Lost Wgt * Lost Cost[P!] + Transport Wgt * Transport Cost[P!] )
	~ Dmnl ~
	~ :SUPPLEMENTARY
 |

Total Delivered = ZIDZ ( SUM ( Product Delivered[P!] ) , SUM ( Initial Supply[P!,O!,D\
		!] ) )
	~ Dmnl ~
	~ :SUPPLEMENTARY
 |

Total In Transit = ZIDZ ( SUM ( Transport[P!,O!,T!,D!] ) , SUM ( Initial Supply[P!,O!\
		,D!] ) )
	~ Dmnl ~
	~ :SUPPLEMENTARY
 |

Total Lost = ZIDZ ( SUM ( Product Lost[P!] ) , SUM ( Initial Supply[P!,O!,D!] ) )
	~ Dmnl ~
	~ :SUPPLEMENTARY
 |

Total Unsold = ZIDZ ( SUM ( Origin[P!,O!,D!] ) , SUM ( Initial Supply[P!,O!,D!] ) )
	~ Dmnl ~
	~ :SUPPLEMENTARY
 |

Trans Draw[T] = SAMPLE IF TRUE( MODULO ( Time , Trans Freq ) = 0, RANDOM BINOMIAL ( 0\
		, 1, 1 - Trans Prob , 1, 0, 1, 0) , 1)
	~ Dmnl [0,1,0.2] ~ |

Trans Dur = 2
	~  [0,100,5]
	~ RANDOM BINOMIAL(0, 100, Dur Prob, 100, 0, 1, 0) |

Trans Fail[T] = IF THEN ELSE ( Trans Draw[T] = 0, ( 1 - PULSE ( Trans Time , Trans Dur\
		) ) , 1)
```

```
	~ Dmnl ~ |

Trans Freq = 4
	~ Day [0,20,2]
	~ RANDOM BINOMIAL(0, 50, Freq Prob, 50, 0, 1, 0) |

Trans Prob = 0.1
	~  [0,1,0.1] ~ |

Trans Time = SAMPLE IF TRUE( MODULO ( Time , Trans Freq ) = 0, Time , 0)
	~ Dmnl [0,1,0.2] ~ |

Trans Total = SUM ( Trans Fail[T!] )
	~ Dmnl ~
	~ :SUPPLEMENTARY
|

Transport[P,O,T,D] = INTEG( OtoT Rate[P,O,T,D] - SUM ( TtoT Rate[P,O,T,X!,D] ) + SUM \
		( TtoT Rate[P,O,Y!,T,D] ) - TtoD Rate[P,O,T,D] - TtoL Rate[P,O,T,D] , 0)
	~ Widgets ~ |

Transport Cost[P] = ZIDZ ( SUM ( Transport[P,O!,T!,D!] ) , SUM ( Initial Supply[P,O!,\
		D!] ) ) / 10
	~ Dmnl
	~ ZIDZ ( ZIDZ ( SUM ( Transport[P,O!,T!,D!] ) , SUM ( Initial \
		Supply[P,O!,D!] ) ) / 10, Time ) |

Transport Wgt = 0.9
	~ Dmnl [0,1,0.1] ~ |

TtoD Alloc[T,D] = GET XLS CONSTANTS('?Data', 'Simple', 'TtoD')
	~ Dmnl ~ |

TtoD Rate[P,O,T,D] = MAX ( 0, Transport[P,O,T,D] * Trans Fail[T] * Dest Fail[D] * TtoD Alloc\
		[T,D] ) / TtoD Time
	~ Widgets/Day ~ |

TtoD Time = 3
	~ Day [1,100,1] ~ |

TtoL Rate[P,O,T,D] = IF THEN ELSE ( Transport[P,O,T,D] - Vol Delayed[P,O,T,D] < 0.01 \
		:AND: Transport[P,O,T,D] > 0.01, MAX ( 0, Transport[P,O,T,D] ) , 0) / TIME STEP
	~ Widgets/Day ~ |
```

```
TtoT Rate[P,O,X,Y,D] = MAX ( 0, MIN ( Max Capacity , MAX ( 0, Network[X,Y] * ( Transport\
		[P,O,X,D] ) ) ) ) / TtoT Time
	~ Widgets/Day ~ |

TtoT Time = 3
	~ Day [0,100,1] ~ |

Vol Delayed[P,O,T,D] = DELAY FIXED ( Transport[P,O,T,D] ,Delay , 0)
	~ Widgets ~ |

X <-> T ~  ~ |

Y <-> T ~  ~ |

********************************************************
	.Control
********************************************************~
		Simulation Control Parameters
	|

FINAL TIME = 100
	~ Week [0,100,10]
	~ The final time for the simulation. |

INITIAL TIME = 0
	~ Week
	~ The initial time for the simulation. |

SAVEPER = TIME STEP
	~ Week [0,?]
	~ The frequency with which output is stored. |

TIME STEP = 0.25
	~ Week [0,?]
	~ The time step for the simulation. |

\\\---/// Sketch information - do not modify anything except names
V300  Do not put anything below this section - it will be ignored
*Dashboard
$192-192-192,0,Times New Roman|12||0-0-0|0-0-0|0-0-255|-1--1--1|192-192-192|96,96,70,0
12,1,0,227,753,111,118,3,135,0,19,3,0,0,0,128-0-128,0-0-0,|12|B|128-0-128
TIME
```

12,2,0,226,470,110,117,3,135,0,19,3,0,0,0,255-0-0,0-0-0,|12|B|255-0-0
FAILURE FREQUENCY
12,3,0,225,1032,111,118,3,135,0,19,3,0,0,0,0-128-0,0-0-0,|12|B|0-128-0
OTHER
12,4,0,228,179,111,124,3,135,0,19,3,0,0,0,0-0-255,0-0-0,|12|B|0-0-255
FAILURE PROBABILITY
12,5,8653030,225,243,80,20,3,124,0,0,0,0,0,0
Dest Prob,0,1,0.1
12,6,7864532,225,104,80,20,3,124,0,0,0,0,0,0
Orig Prob,0,1,0.1
12,7,28967324,225,173,80,20,3,124,0,0,0,0,0,0
Trans Draw,0,1,0.2
12,8,7733424,223,393,80,20,3,124,0,0,0,0,0,0
Orig Freq,0,20,1
12,9,94110356,223,461,80,20,3,124,0,0,0,0,0,0
Trans Freq,0,20,2
12,10,113710650,221,1090,80,20,3,124,0,0,0,0,0,0
Lost Wgt,0,1,0.1
12,11,4458902,221,959,80,20,3,124,0,0,0,0,0,0
Delay,0,200,10
12,12,15405266,221,1027,80,20,3,124,0,0,0,0,0,0
Transport Wgt,0,1,0.1
12,13,0,231,45,40,20,8,3,0,18,-1,0,0,0,-1--1--1,0-0-0,|12|B|0-0-255
12,14,6491918,223,537,80,20,3,124,0,0,0,0,0,0
Dest Freq,0,20,1
12,15,0,226,-17,143,46,8,135,0,8,-1,0,0,0,-1--1--1,0-0-0,|18||0-0-0
FAILURE ANALYSIS AND MODELING ENVIRONMENT (FAME)
12,16,15011630,223,675,80,20,3,124,0,0,0,0,0,0
OtoT Time,1,10,1
12,17,3149930,223,746,80,20,3,124,0,0,0,0,0,0
TtoT Time,10,100,10
12,18,9506506,223,817,80,20,3,124,0,0,0,0,0,0
TtoD Time,10,100,10
12,19,6098802,1896,145,298,204,3,188,0,0,2,0,0,0
Total Cost,Graph
12,20,10621728,688,558,304,203,3,188,0,0,2,0,0,0
Product Delivered,Graph
12,21,5771486,688,969,305,203,3,188,0,0,2,0,0,0
Transport,Table
12,22,10556116,1297,969,299,203,3,188,0,0,2,0,0,0
Destination,Table
12,23,12783286,688,148,304,203,3,188,0,0,2,0,0,0
Transport Cost,Graph

12,24,297863832,1295,147,298,204,3,188,0,0,2,0,0,0
Lost Cost,Graph
12,25,13111640,1897,557,298,204,3,188,0,0,2,0,0,0
Total Delivered,Graph
12,26,6165128,1296,558,298,204,3,188,0,0,2,0,0,0
Product Lost,Graph
12,27,8325680,1897,968,297,203,3,188,0,0,1,0,0,0
Delivered_vs_Cost
\\\---/// Sketch information - do not modify anything except names
V300 Do not put anything below this section - it will be ignored
*Main
$192-192-192,0,Times New Roman|12||0-0-0|0-0-0|0-0-255|-1--1--1|-1--1--1|96,96,60,0
12,1,0,2131,203,298,204,3,188,0,0,2,0,0,0
Total Cost,Graph
10,2,Transport,305,429,52,27,3,131,0,0,0,0,0,0
10,3,Destination,501,428,52,27,3,131,0,0,0,0,0,0
10,4,Initial Supply,98,356,26,20,8,131,0,0,0,0,0,0
12,5,0,923,616,304,203,3,188,0,0,2,0,0,0
Product Delivered,Graph
10,6,TtoT Time,220,601,26,23,8,131,0,0,-1,0,0,0
1,7,9,2,4,0,0,22,0,0,0,-1--1--1,,3|(264,532)|(264,539)|(264,497)|
1,8,9,2,100,0,0,22,0,0,0,-1--1--1,,3|(340,532)|(340,531)|(340,493)|
11,9,1756,305,532,6,8,34,131,0,0,1,0,0,0
10,10,TtoT Rate,305,566,28,26,40,131,0,0,-1,0,0,0
10,11,Assigned,205,666,30,11,8,3,0,0,0,0,0,0
10,12,Network,304,624,30,11,8,3,0,0,0,0,0,0
10,13,TtoD Alloc,396,381,33,21,8,131,0,0,-1,0,0,0
1,14,16,3,4,0,0,22,0,0,0,-1--1--1,,1|(426,427)|
1,15,16,2,100,0,0,22,0,0,0,-1--1--1,,1|(374,427)|
11,16,1692,397,427,6,8,34,3,0,0,1,0,0,0
10,17,TtoD Rate,397,462,25,27,40,131,0,0,-1,0,0,0
1,18,13,16,0,0,0,0,0,64,0,-1--1--1,,1|(396,404)|
10,19,FINAL TIME,323,1088,38,23,8,131,0,0,-1,0,0,0
10,20,TtoD Time,396,538,29,25,8,131,0,0,0,0,0,0
12,21,0,923,1027,305,203,3,188,0,0,2,0,0,0
Transport,Table
10,22,Max Capacity,384,598,36,26,8,131,0,0,0,0,0,0
1,23,20,17,0,0,0,0,0,64,0,-1--1--1,,1|(396,508)|
10,24,Orig Prob,94,909,23,21,8,131,0,0,0,0,0,0
10,25,Dest Prob,522,914,23,23,8,131,0,0,0,0,0,0
10,26,Orig Fail,13,840,23,21,8,131,0,0,0,0,0,0
10,27,Trans Fail,227,840,23,20,8,131,0,0,0,0,0,0
10,28,Dest Fail,444,844,22,25,8,131,0,0,0,0,0,0

1,29,2,17,1,0,0,0,0,64,0,-1--1--1,,1|(371,478)|
1,30,2,9,0,0,0,0,0,64,0,-1--1--1,,1|(305,484)|
1,31,6,10,1,0,0,0,0,64,0,-1--1--1,,1|(257,574)|
10,32,Time,155,371,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,33,Time,128,388,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,34,Time,145,79,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,35,Transport Cost,98,276,38,19,8,131,0,0,0,0,0,0
10,36,Time,438,42,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
1,37,12,10,0,0,0,0,0,128,0,-1--1--1,,1|(304,609)|
10,38,Optional,393,666,28,11,8,3,0,0,0,0,0,0
10,39,Time,416,46,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,40,Time,154,54,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,41,Fraction,303,667,27,11,8,131,0,0,0,0,0,0
1,42,11,41,0,0,0,0,0,128,1,-1--1--1,,1|(248,666)|
10,43,Time,123,850,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
1,44,4,48,0,0,0,0,0,128,1,-1--1--1,,1|(98,382)|
12,45,0,1532,1027,299,203,3,188,0,0,2,0,0,0
Destination,Table
12,46,0,923,206,304,203,3,188,0,0,2,0,0,0
Transport Cost,Graph
12,47,0,1530,205,298,204,3,188,0,0,2,0,0,0
Lost Cost,Graph
10,48,Origin,99,429,50,27,3,131,0,0,0,0,0,0
1,49,51,2,4,0,0,22,0,0,0,-1--1--1,,1|(225,430)|
1,50,51,48,100,0,0,22,0,0,0,-1--1--1,,1|(167,430)|
11,51,1116,192,430,6,8,34,3,0,0,1,0,0,0
10,52,OtoT Rate,192,462,24,24,40,131,0,0,-1,0,0,0
10,53,OtoT Alloc,192,370,32,24,8,131,0,0,0,0,0,0
1,54,53,51,0,0,0,0,0,128,0,-1--1--1,,1|(192,402)|
1,55,48,52,1,0,0,0,0,64,0,-1--1--1,,1|(136,485)|
10,56,OtoT Time,191,541,29,22,8,131,0,0,-1,0,0,0
1,57,56,52,0,0,0,0,0,64,0,-1--1--1,,1|(191,509)|
12,58,0,2132,615,298,204,3,188,0,0,2,0,0,0
Total Delivered,Graph
10,59,Supply Train,98,524,31,21,8,131,0,0,0,0,0,0
10,60,Dur,5,558,17,14,8,131,0,0,-1,0,0,0
1,61,60,59,0,0,0,0,0,64,0,-1--1--1,,1|(37,545)|
10,62,INITIAL TIME,37,321,60,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,63,Rep,5,607,15,11,8,3,0,0,-1,0,0,0
1,64,63,59,0,0,0,0,0,64,0,-1--1--1,,1|(40,575)|
10,65,Product Volume,98,597,34,20,8,131,0,0,0,0,0,0
1,66,65,59,0,0,0,0,0,128,0,-1--1--1,,1|(98,568)|
10,67,End,6,508,14,11,8,3,0,0,-1,0,0,0

1,68,67,59,0,0,0,0,0,64,0,-1--1--1,,1|(36,512)|
10,69,Start,5,453,17,11,8,3,0,0,-1,0,0,0
1,70,69,59,0,0,0,0,0,64,0,-1--1--1,,1|(38,479)|
1,71,41,12,1,0,0,0,0,128,0,-1--1--1,,1|(303,650)|
1,72,38,41,0,0,0,0,0,128,1,-1--1--1,,1|(354,666)|
10,73,Time,245,67,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,74,Product Delivered,496,349,43,27,8,131,0,0,0,0,0,0
12,75,0,1531,616,298,204,3,188,0,0,2,0,0,0
Product Lost,Graph
10,76,Time,373,-15,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,77,Time,574,-22,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,78,Time,351,6,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,79,Time,243,94,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
12,80,0,2132,1026,297,203,3,188,0,0,1,0,0,0
Delivered_vs_Cost
10,81,Time,329,-22,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,82,Time,336,-25,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,83,Total Delivered,497,275,40,24,8,131,0,0,0,0,0,0
10,84,Product Lost,305,213,51,26,3,131,0,0,0,0,0,0
1,85,86,84,4,0,0,22,0,0,0,-1--1--1,,1|(306,269)|
11,86,828,306,306,8,6,33,3,0,0,2,0,0,0
10,87,TtoL Rate,271,306,27,24,40,131,0,0,-1,0,0,0
1,88,86,2,100,0,0,22,0,0,0,-1--1--1,,1|(306,357)|
10,89,Initial Supply,498,212,36,26,8,130,0,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,90,Total Lost,408,213,26,18,8,131,0,0,0,0,0,0
1,91,84,90,0,0,0,0,0,128,0,-1--1--1,,1|(362,213)|
10,92,Total Cost,99,214,27,21,8,131,0,0,0,0,0,0
10,93,Time,353,1111,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
1,94,89,90,0,0,0,0,0,128,0,-1--1--1,,1|(455,212)|
1,95,74,83,0,0,0,0,0,128,0,-1--1--1,,1|(496,317)|
1,96,22,10,0,0,0,0,0,64,0,-1--1--1,,1|(346,583)|
10,97,Time,300,1185,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,98,Time,300,1132,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,99,Time,106,24,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,100,Time,208,680,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,101,Time,168,195,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,102,Time,423,1242,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,103,Time,423,1242,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,104,Time,168,195,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
1,105,2,87,1,0,0,0,0,64,0,-1--1--1,,1|(293,359)|
10,106,Time,404,1109,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,107,Vol Delayed,393,306,46,14,8,131,0,0,0,0,0,0
1,108,107,86,0,0,0,0,0,128,0,-1--1--1,,1|(337,306)|

10,109,Time,112,818,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,110,Orig Freq,94,770,25,21,8,131,0,0,-1,0,0,0
1,111,26,52,0,1,0,0,0,128,0,-1--1--1,,1|(97,658)|
10,112,Time,245,852,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,113,Trans Freq,308,773,25,19,8,131,0,0,-1,0,0,0
10,114,Trans Draw,310,839,28,23,8,131,0,0,-1,0,0,0
10,115,Dest Freq,526,773,24,23,8,131,0,0,-1,0,0,0
10,116,Time,444,720,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
1,117,28,17,0,1,0,0,0,128,0,-1--1--1,,1|(421,660)|
1,118,27,12,0,1,0,0,0,128,0,-1--1--1,,1|(264,734)|
1,119,27,52,0,1,0,0,0,128,0,-1--1--1,,1|(210,659)|
1,120,27,17,0,1,0,0,0,128,0,-1--1--1,,1|(306,660)|
10,121,Orig Total,13,911,22,25,8,131,0,0,0,0,0,0
10,122,Trans Total,226,905,26,22,8,131,0,0,0,0,0,0
10,123,Dest Total,444,917,24,24,8,131,0,0,0,0,0,0
1,124,26,121,0,0,0,0,0,128,0,-1--1--1,,1|(13,866)|
1,125,27,122,0,0,0,0,0,128,0,-1--1--1,,1|(226,864)|
1,126,28,123,0,0,0,0,0,128,0,-1--1--1,,1|(444,874)|
10,127,Time,77,792,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,128,Time,280,788,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,129,Time,487,787,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
1,130,89,83,1,0,0,0,0,128,0,-1--1--1,,1|(501,252)|
1,131,16,74,1,0,0,0,0,128,0,-1--1--1,,1|(431,411)|
10,132,Time,16,608,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,133,Delay,392,252,20,11,8,3,0,0,0,0,0,0
1,134,133,107,0,0,0,0,0,128,0,-1--1--1,,1|(392,270)|
10,135,Lost Wgt,18,232,31,11,8,3,0,0,-1,0,0,0
1,136,135,92,0,0,0,0,0,128,0,-1--1--1,,1|(53,224)|
10,137,Lost Cost,191,214,24,19,8,131,0,0,-1,0,0,0
1,138,137,92,0,0,0,0,0,64,0,-1--1--1,,1|(153,214)|
1,139,35,92,0,0,0,0,0,64,0,-1--1--1,,1|(98,253)|
10,140,Transport Wgt,18,176,47,11,8,3,0,0,-1,0,0,0
1,141,140,92,0,0,0,0,0,64,0,-1--1--1,,1|(50,191)|
1,142,84,137,0,0,0,0,0,128,0,-1--1--1,,1|(241,213)|
1,143,4,137,1,0,0,0,0,64,0,-1--1--1,,1|(161,283)|
10,144,Time,-98,170,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
1,145,4,35,0,0,0,0,0,64,0,-1--1--1,,1|(98,322)|
1,146,2,35,1,0,0,0,0,64,0,-1--1--1,,1|(201,287)|
1,147,59,48,0,0,0,0,0,128,0,-1--1--1,,1|(98,486)|
1,148,2,107,0,0,0,0,0,128,0,-1--1--1,,1|(348,366)|
10,149,TIME STEP,211,1086,50,11,8,2,0,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,150,Total Unsold,6,353,33,26,8,131,0,0,0,0,0,0
1,151,48,150,1,0,0,0,0,128,0,-1--1--1,,1|(56,394)|

1,152,4,150,1,0,0,0,0,64,0,-1--1--1,,1|(62,354)|
10,153,Time,91,465,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,154,Total In Transit,195,321,35,22,8,131,0,0,0,0,0,0
1,155,2,154,1,0,0,0,0,128,0,-1--1--1,,1|(271,357)|
1,156,4,154,1,0,0,0,0,128,0,-1--1--1,,1|(144,329)|
10,157,TIME STEP,241,133,50,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
1,158,157,87,0,1,0,0,0,64,0,-1--1--1,,1|(252,206)|
10,159,Trans Prob,308,906,26,21,8,131,0,0,0,0,0,0
10,160,Time,337,669,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
1,161,160,114,0,1,0,0,0,64,0,-1--1--1,,1|(325,741)|
10,162,Trans Dur,154,840,23,23,8,131,0,0,-1,0,0,0
1,163,162,27,0,0,0,0,0,64,0,-1--1--1,,1|(183,840)|
10,164,Time,233,748,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
10,165,Trans Time,226,774,27,21,8,131,0,0,-1,0,0,0
1,166,165,27,0,0,0,0,0,128,0,-1--1--1,,1|(226,800)|
10,167,Time,144,678,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
1,168,167,165,0,1,0,0,0,64,0,-1--1--1,,1|(175,715)|
1,169,113,165,0,0,0,0,0,64,0,-1--1--1,,1|(275,773)|
1,170,159,114,0,0,0,0,0,64,0,-1--1--1,,1|(308,880)|
1,171,114,27,0,0,0,0,0,128,0,-1--1--1,,1|(273,839)|
1,172,113,114,0,0,0,0,0,128,0,-1--1--1,,1|(308,797)|
10,173,Orig Time,13,770,22,21,8,131,0,0,0,0,0,0
10,174,Orig Draw,95,839,26,21,8,131,0,0,0,0,0,0
10,175,Orig Dur,-57,838,22,23,8,131,0,0,0,0,0,0
1,176,175,26,0,0,0,0,0,128,0,-1--1--1,,1|(-28,838)|
1,177,110,174,0,0,0,0,0,128,0,-1--1--1,,1|(94,797)|
1,178,173,26,0,0,0,0,0,128,0,-1--1--1,,1|(13,798)|
10,179,Time,129,760,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
1,180,179,174,0,1,0,0,0,64,0,-1--1--1,,1|(117,788)|
1,181,24,174,0,0,0,0,0,128,0,-1--1--1,,1|(94,881)|
1,182,174,26,0,0,0,0,0,128,0,-1--1--1,,1|(59,839)|
10,183,Time,16,689,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
1,184,183,173,0,1,0,0,0,64,0,-1--1--1,,1|(14,717)|
1,185,110,173,0,0,0,0,0,64,0,-1--1--1,,1|(59,770)|
10,186,Dest Time,444,773,23,21,8,131,0,0,0,0,0,0
10,187,Dest Draw,526,844,24,21,8,131,0,0,0,0,0,0
10,188,Dest Dur,374,842,24,24,8,131,0,0,0,0,0,0
1,189,186,28,0,0,0,0,0,128,0,-1--1--1,,1|(444,799)|
1,190,115,186,0,0,0,0,0,128,0,-1--1--1,,1|(491,773)|
1,191,188,28,0,0,0,0,0,128,0,-1--1--1,,1|(403,842)|
1,192,187,28,0,0,0,0,0,128,0,-1--1--1,,1|(491,844)|
1,193,115,187,0,0,0,0,0,128,0,-1--1--1,,1|(526,802)|
1,194,25,187,0,0,0,0,0,128,0,-1--1--1,,1|(523,884)|

10,195,Time,548,772,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
1,196,195,187,0,1,0,0,0,64,0,-1--1--1,,1|(540,796)|
10,197,Time,458,695,26,11,8,2,1,3,-1,0,0,0,128-128-128,0-0-0,|12||128-128-128
1,198,197,186,0,1,0,0,0,64,0,-1--1--1,,1|(453,722)|
1,199,140,135,0,0,0,0,0,128,0,-1--1--1,,1|(18,197)|
12,200,0,2131,203,298,204,3,188,0,0,2,0,0,0
Total Cost,Graph
12,201,0,2132,615,298,204,3,188,0,0,2,0,0,0
Total Delivered,Graph