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Analyzing The Supply Chain Operation Of A Fast-Food Restaurant Using Simulation Modeling And Developing A Cost Estimation Optimization Model In The Disruption Period

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ANALYZING THE SUPPLY CHAIN OPERATION OF A FAST-FOOD RESTAURANT USING SIMULATION MODELING AND DEVELOPING A COST ESTIMATION OPTIMIZATION MODEL IN THE DISRUPTION PERIOD

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Supply chain operation performance is a much-discussed topic over the last decade which will lead to optimizing the resources required to provide the necessary level of customer service to a specific segment and improve customer service through increased product availability and reduced order cycle time. During disruption in supply chain, performance parameter changes, and the overall supply chain cost at each stage increases. External factors such as labor shortages, delayed and costly supplies, and decreased demand also contribute to this cost. This thesis work presents a research-focused analysis of a small pizza shop, under circumstances that include the loss of employees, suppliers and delays, and analyzed the increased cost of supplies. As part of this research, a predictive simulation model of the working flow and supply chain of the restaurant using SIMIO software was created to evaluate the effects of adjusting shift resources and switching replenishment strategies. the goal of this research was to help determine the optimal resources allocation at each workstation according to availability and utilization. the simulation model explored the impact of supplier replenishment on the shop's key performance indicators (KPIs). the research evaluated various scenarios and experiments to evaluate the outputs (i.e., KPIs) and provided recommendations to improve the shop's resource allocation. Finally, a cost estimation optimization model was developed to work under supply chain disruption scenarios.

1. INTRODUCTION & BACKGROUND

A supply chain includes all operations required to transform raw materials into finished goods, including procurement, component production, final assembly, distribution to end markets, and all required material handling and storage (or logistics) activities. Often, it addresses the processing of product return flows and potential material and component reuse, referred to as closed-loop supply chains. End-to-end supply chains, which involve many businesses and organizations working together in a chain or system to complete these operations, are the exception rather than the rule (Zijm et al., 2019). Uncertainty related to supply chain disruptions is a significant barrier to establishing a smooth supply chain and recognizing and understanding sources of uncertainty, and their influence on other operations throughout the supply chain is critical because it can affect the total planning. (Schunk & Plott, 2000).

Unplanned and unforeseen incidents that interfere with the regular flow of supplies and materials through a supply chain are referred to as supply chain disruptions. Maintaining product quality from beginning to end and ensuring that all resources used are of the highest caliber require a well-organized supply chain (Craighead et al., 2007). For example, numerous sectors were impacted by the unexpected Covid-19 outbreak, which severely interrupted global supply networks resulting in significant loss for the industry owners. Different industrial disruptions were felt everywhere and were well-known for their considerable economic impact. As more people began working from home, the need for electronic devices increased to support their daily activities which changed the market for semiconductors from industrial to consumer electronics, resulting in a significant impact on the automotive industry. Due to this scarcity, it became clear that microchip supply chains might be expanded and that production did not need to be solely dependent on the few factories that create most of the world's semiconductors. An example of a potential human mistake regarding cargo consolidation and disturbance is the notorious 'Ever Given' cargo ship's blockade of the Suez Canal in 2021. the cargo ship prevented international trade from operating for about 7 days, causing losses of roughly $10 billion daily. the Suez Canal Authority has responded by planning an extension project for the canal, which is planned to be finished by July 2023. the epidemic had a major impact on the retail sector as well. Figure 1 depicts the global supply chain disruption from 2019 to 2021.

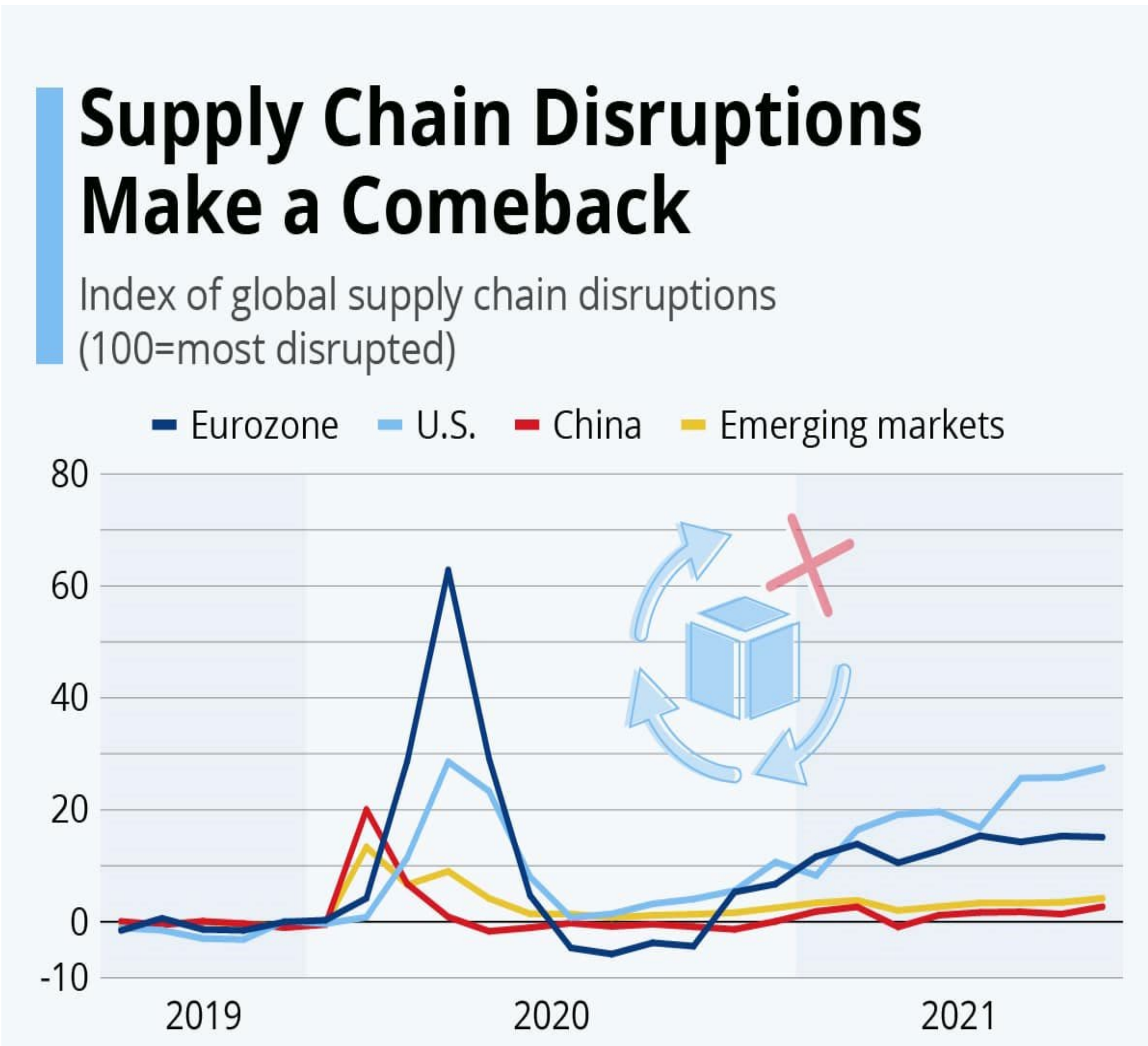


Figure 1: Supply Chain Disruptions in Recent Year in Different Parts of the Worlds
(Buchholz, K., 2022)

In 2020, a total of 12,000 businesses shuttered in the US as customers shifted to online shopping and rejected traditional brick and mortar retailers. Brexit is just another instance of factor that disrupts the supply chain and shares a huge loss. This geopolitical shift had an impact on how manufacturers sourced, transported, assembled, priced, and made their products available to consumers (Reyes, 2022). Indeed, managers must deal with supply chain disruptions brought on by a variety of factors, such as inadequate supplier-to-manufacturer communication, opportunistic supplier behavior, truck driver or port worker strikes, terrorist attacks, IT issues, industrial accidents, quality issues, operational issues, natural disasters, and governmental regulations. These hiccups frequently result in significant financial losses, missed sales, and adverse effects on shareholder wealth and corporate performance (Macdonald & Corsi, 2013). Various types of supply chain disruptions are illustrated in Figure 2.

Figure 2: Different Types of Supply Chain Disruptions(Slide Team, n.d.)

Supply chain disruptions are being recognized by managers and researchers as serious hazard that needs to be properly addressed. To better comprehend these disruptions, their origins, the elements that mitigate or impact them, and to discover and compare various tactics and policies for coping with such disturbances, researchers must first create knowledge of these disruptions. A complement strategy with empirical research is required if we want to better understand supply chain disruptions, how to define them, what variables impact them and how, and what strategies may be employed to cope with them (Melnyk et al., 2009). Different aspects of resilient supply chain is shown in Figure 3.

Figure 3: Resilient Supply Chain(TIBCO, n.d.)

Various industry supply chain management including energy, food, electronics, pharmacy, etc., and identified the potential risks associated with modern-day supply systems need to implement a flexible and transparent supply chain system that dynamically addresses the supply chain risks and pivots as per the need (Christopher & Peck, 2004). In the Covid-19 outbreak, a significant supply chain disruption has happened in the restaurant business too. While the intensity of the epidemic varies by US area and community, almost every state and local government has enforced physical separation rules by outlawing dine-in services at eateries. While limiting interpersonal contact and slowing the virus's transmission, these intervention measures pose a serious danger to the sustainability of the restaurant sector. Approximately 60% of US restaurants were forced to close because of financial difficulty brought on by the loss of dine-in customers, according to a National Restaurant Association study of 6,500 restaurant owners conducted in mid-April (Yang et al., 2020b). Meanwhile, sales at sit-down restaurants, fast-food restaurants, coffee shops, and other venues for informal eating decreased by 27% (Felix et al., 2020). According to the foot traffic restaurant visit model, stay-at-home orders were linked to a 3.25% loss in demand whereas a 1% rise in daily new COVID-19 instances resulted in a 0.0556% decline in restaurant demand. Areas with a higher concentration of Asian Americans, Democratic voters, dine-in restaurant patrons in the previous year, and a higher degree of restaurant diversity had an enhanced negative impact due to this disruption in supply chain management (Yang et al., 2020a). the impact of supply chain disruption in different industries is illustrated in Figure 4.

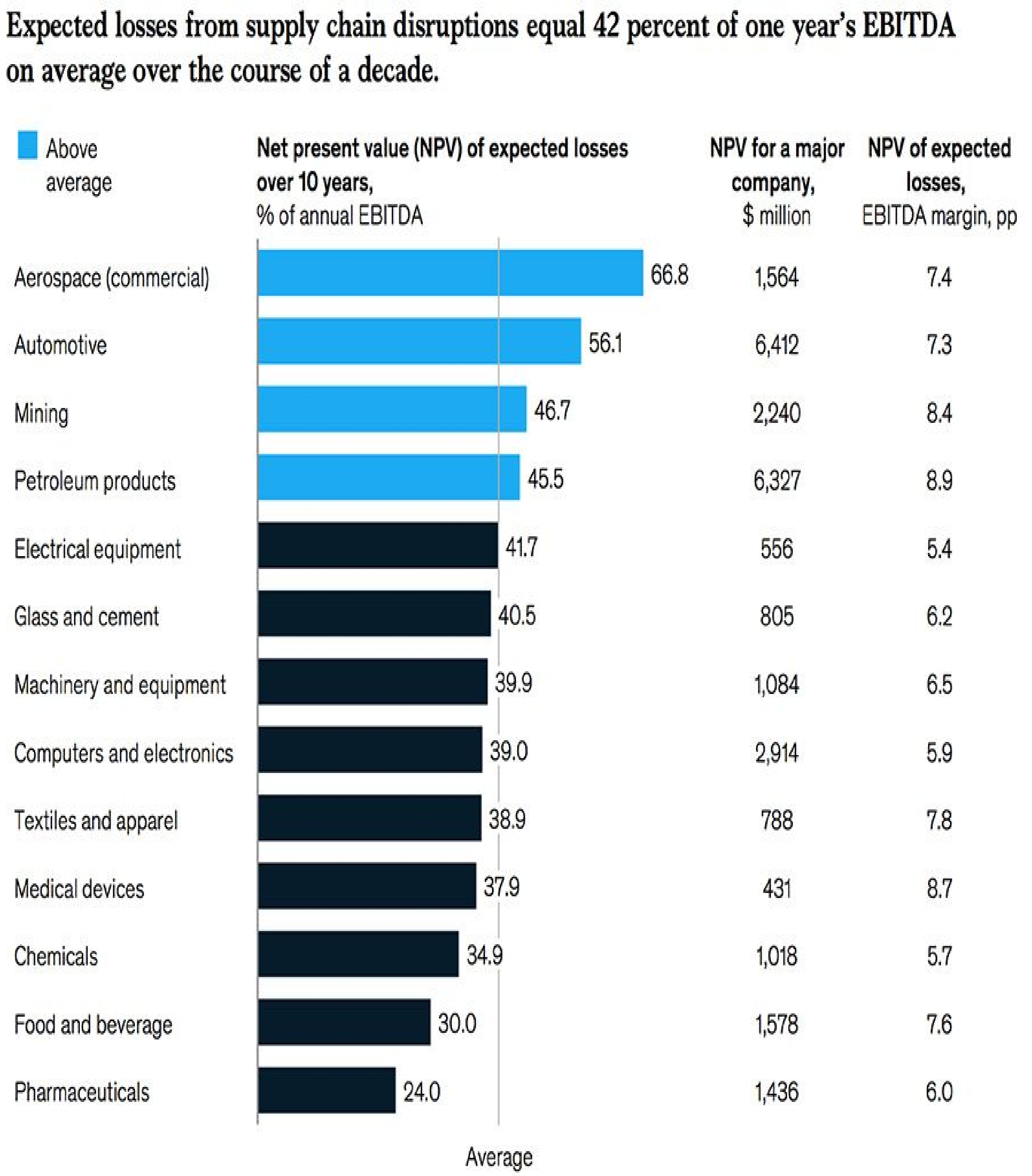


Figure 4: Effects of Supply Chain Disruptions in Different Sectors *(McKinsey & Company, 2020)*

Fuzzy analytical hierarchy process (AHP) and fuzzy TOPSIS have been used for preference ranking of 3PL risks in the restaurant supply chain and obtaining risk index value and results indicate that macro-level risks like the risks associated with 3PL in the restaurant supply chain due to political agitation in the district, cataclysmic events, ailments like COVID-19, bird influenza etc. are the most relevant first-level risk with high-risk index as well as high relative weight. On the other hand, as per the analysis of second-level risks, the occurrence of cataclysmic events holds the most elevated risk index value (Shanker et al., 2021).

Many studies are going on measuring food supply chain performance, so different methods came in different time periods. Delphi technique and case study-based research are done in 2010. A balanced scorecard (BSC) model was designed and delimited for performance measurement of the food supply chain. the resulting BSC model was tested on two companies operating in the food industry, for final validation and the results show that the companies examined have a similar view for three of the four perspectives of the BSC. the fact that a specific industry field was examined could be seen as a limitation of the work as the results presented are not suitable to be generalized or extended to other contexts (Bigliardi & Bottani, 2010).

Supply chain performance was also measured in terms of three key dimensions: Cost, Time and Reliability. After collecting the survey on 44 local SMEs, the results were compared with existing performance benchmarks and within the benchmarked group itself and a high performing multinational firm to see whether the developed tool could identify performance gaps in the trial group (Banomyong & Supatn, 2011). the overall cost is an essential factor for any supply chain. Another study analyzing the problem of facility location and vehicle routing for an efficient logistics system in a practical case study application was done in 2016. the research was done to redesign the logistics network of a franchise company in the food industry in the city of Puebla,

Puebla (Mexico). A P-median model was presented to propose locations for installing new distribution centers, followed by applying a CVRP to determine the optimal distribution routes between the initial depot and corresponding demand points (Chancey et al., 2016).

As restaurant patron demand fell, a phenomenon known as the ripple effect or disruption propagation began to affect the whole supply chain network. An operational failure at one Supply Chain Network (SCN) company that results in operating losses for other business entities is referred to as disruption propagation or ripple effect (Li et al., 2021). Food production, conversion, and delivery enterprises must deal with a web of interconnected risks and uncertainties at every stage of the value chain, from farmers to end-user channels. Due to restaurants closing temporarily or permanently to stop the spread of the virus, several food-service suppliers faced order cancellations and client losses. Due to the closure of these restaurants, suppliers were left with a large number of goods in their storage spaces that required refrigeration, increasing their expenses (Felix et al., 2020). the distribution of stimulus checks resulted in some brief spikes in demand, but they had little impact on income. However, these stimulus payments boosted economic activity and consumption, particularly among low- and middle-income households (Yang et al., 2020b).

As food security is one of the vital aspects of food systems that are directly affected by supply chain disruption, during epidemics and pandemics before moving on to panic buying, food shortages, and price spikes need to be observed during the current crisis. A focus on the importance of food resilience, together with the need for addressing issues related to food loss and food waste are needed to develop contingency plans and mitigation strategies that would allow a more rapid response to extreme events (e.g., disasters from climate change) and transform the food sector by making it more resilient ((Boyacı-Gündüz et al., 2021). the food supply chain network is shown in Figure 5.

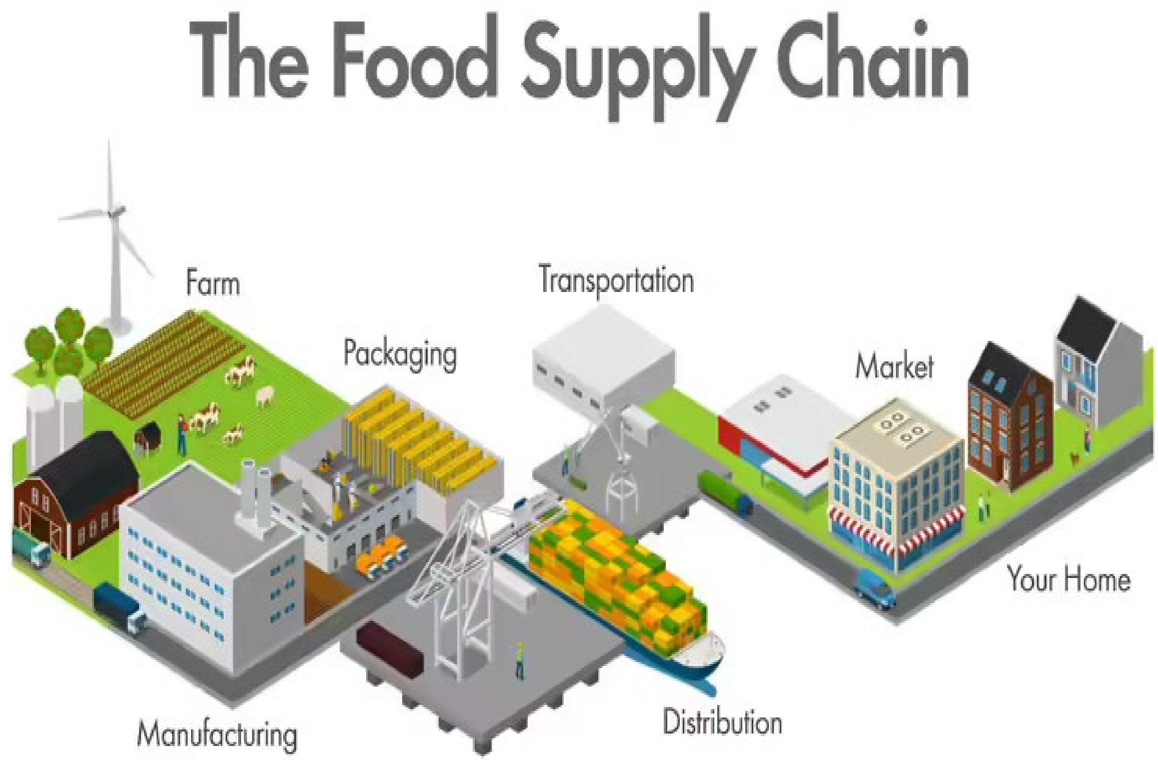


Figure 5: The Food Supply Chain (Patrick J. Kiger, 2020)

A recent study to tackle strategic issues for the food supply chain through system dynamics was done on both single-echelon and multi-echelon supply chain networks. the model could be used to identify effective policies' optimal parameters for various strategic decision-making problems and presented the optimal capacity while varying operational parameters (Georgiadis et al., 2005).

Simulation is one of the important tools for studying supply chain because it can handle unpredictability. To simulate a system, an artificial history of the system must be created and observed in order to make conclusions about the operational features of the real system. For the resolution of many real-world issues, simulation is a crucial approach to problem-solving because without physically implementing the system, businesses may utilize simulation to determine how successful and expensive a cutting-edge inventory system like just-in-time could be in their local context. When describing and analyzing a system's behavior, posing hypothetical "what-if" scenarios, and helping with the design of actual systems, simulation is employed to mimic the behavior so that decisions can be made easily. Simulation may be used to represent both actual and hypothetical systems for that decision-making purpose (Banks, 2000).

the practice of using computerized simulation has been utilized for various problem-solving, case studies, and tradeoff studies between solutions from a long ago. the first attempt to formally identify and define the various methods and steps involved in validating computer models was done by Robert G. Sergent (1991) where the various verification models for the simulation results at that time were summarized. A standard validation approach combining the inputs from the case users as well as the model makers suggesting running a face validation test on each conceptual case (Sargent, 1991). Farahmand et al. (YEAR) utilized this validated simulation strategy to implement a computer simulation of a growing fast-food chain in the US, using the various user cases, to develop a set of recommendations to increase management efficiency.

A similar type of study was performed on a fast-food shop at the University of Michigan using the simulated model and the investigator identified the existing utilization of the staff, proposing a further combination of staff, work schedules, and workspace reallocation to increase the customer lead times (Farahmand & Martinez, 1996). Simulation in supply chain management is shown in Figure 6.

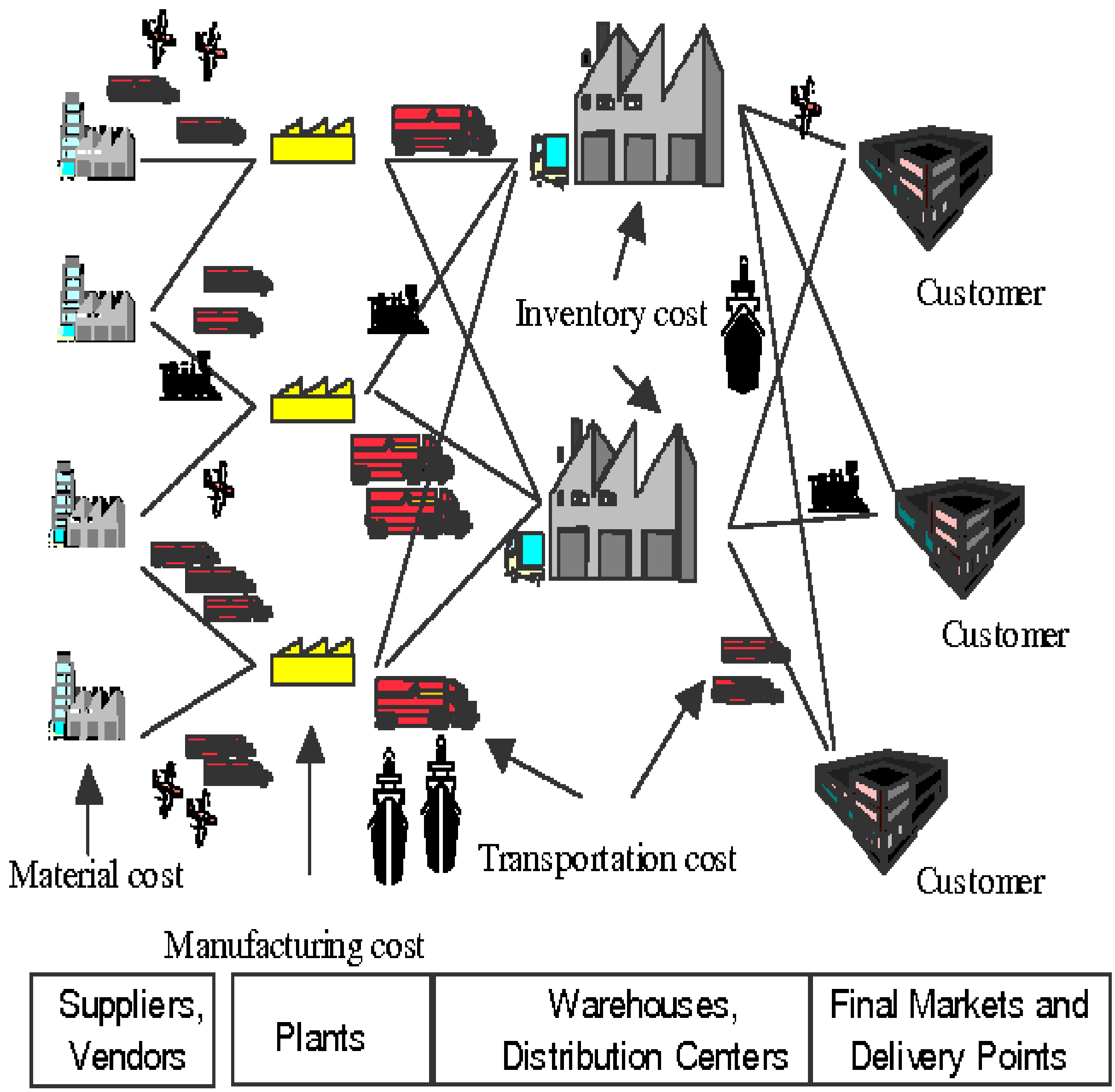


Figure 6: Simulation in Supply Chain Management (Banks et al., 2002)

Since the computerized simulation model can handle a vast amount of operational data and figure out various what-if scenarios, it attracted supply chain researchers to analyze and solve complex modern-day supply chain issues. the computer simulation was used to visualize the effect of various affecting parameters in the regional food supply chain hub. the model was further explored to determine the effectiveness of using incentives for the producers to ship their products on an advanced basis to sustain the regularity in the supply chain of that food hub (Mittal & Krejci, 2015).

In 2016, Mohammad and Thomas combined the SIMIO simulation tool and MATLAB to create an iterative optimization-based Simulation (IOS) model of a manufacturing firm's supply chain to evaluate the performance of their resources (Dehghanimohammadabadi & Keyser, 2017).

Claudia attempted an identical way focusing on the risk assessment and worked on the international supply chain model to figure out a set of actions needed to adopt for managing the risk hurdles so that the supply chain becomes more resilient. They also used the simulation model of that supply chain and validated the performance of the previously proposed actions in various scenarios (Colicchia et al., 2010). In this research we are also experimenting in different scenarios of key performance indicators.

In the context of a restaurant, simulation modeling may be used to investigate the labor productivity needs to optimize sales volume while preserving a high level of customer satisfaction and quick service. Numerous performance indicators, such as wait time, average usage, count of executions, and average delivery time, may be tracked by the model (Brann & Kulick, 2002). the study of issues like scheduling (task sequencing, production scheduling, order release, delivery dependability), capacity planning, process design-service, cellular manufacturing, and resource allocation has long been done using simulation in operations management, logistics, and supply management (Shafer & Smunt, 2004). By changing various elements, including the physical architecture, equipment availability, worker staffing levels, and location, the simulation model enables the user to understand better how the system/restaurant behaves. the simulation offers a platform for analyzing how these factors affect the performance metrics and using the collected data, it can quickly perform several hours' worth of simulated transactions. Before making the modifications to the actual system, it also enables concepts to be vetted and helps with decision-making (Brann & Kulick, 2002). Changes/scenarios that can be carried out and examined include adding new employees, launching a new product, and examining the effects on services.

This research discusses the importance of analyzing disruptions within the food industry supply chains and proposes a model to develop optimal resource allocations to mitigate the effects of such disruptions. Section 2 discusses the methodology used for conducting the research. Section 3 extends the methodology in a model development form. Section 4 summarizes the results of the analysis of various resource combinations. Finally, section 5 provides the key findings from the thesis work and recommendations for future work.

2. METHODOLOGY

2.1 SIMULATION MODELING

A model is a representation of the design and operation of a particular system of interest. A model's ability to forecast the effects of system modifications is one of its goals (Maria, 1997). On the other hand, a simulation is a visual, animated model or module created by a computer that gradually replicates an actual process or system. For the resolution of many real-world issues, simulation is a crucial approach to problem-solving, whereby before making changes to a current system or creating a new one, simulation is used to lower the likelihood that it will fail to fulfill requirements, remove unforeseen bottlenecks, prevent resource under- or over-utilization, and improve system performance. When describing and analyzing a system's behavior, asking "what if" questions regarding the current system, and helping with the design of current systems, simulation is utilized (Banks, 2000). As an illustration, simulation can be used to find the answer: what is the optimal design for a new service system? What resources are needed to support this? How will a system function if the volume of traffic doubles? What effect would a link failure or the absence of possible resources have? It contributes significantly to investigating, evaluating, optimizing, contrasting various scenarios, and foreseeing the impacts. Additionally, it aids in understanding the operational relationships and effects of interactions, as well as solutions for businesses to mitigate business risks (Grikštaitė, 2008).

There are a number of software used for simulation modeling and the most common ones are AnyLogic, Flexsim, Bizagi, NetLogo, Simio, SIMUL8, Vensim etc. Here we will use SIMIO 14 for our simulation modeling. Figure 7 illustrates the google search results for different simulation softwares.

DES Tools	#42 WWW (T)	#43 WWW (TV)	#44 WWW (site)	#45 Google PageRank 2016
	0,5	1	0,5	
	1/3	1/3	1/3	
Arena	30,6	38,9	26,0	2,5
ProModel	20,3	32,4	35,6	2,5
FlexSim	18,2	28,4	32,7	2,0
Simul8	17,1	21,5	22,6	2,0
WITNESS	17,5	24,1	39,4	2,0
ExtendSim	12,1	22,2	15,7	2,5
Simio	17,0	18,6	41,5	2,5
Plant Simulation	22,6	43,1	5,5	2,5
AnyLogic	19,8	19,7	9,9	2,5
SIMPROCESS	17,0	13,0	26,0	2,0
AutoMod	15,7	18,1	4,8	2,5
Micro Saint	11,4	9,5	92,3	2,0
QUEST	14,4	25,2	36,8	3,0
Enterprise Dynami	9,9	16,8	7,9	2,5
ProcessModel	11,8	24,7	71,3	1,5
SimCAD Pro	8,7	13,4	12,9	1,5
GPSS World	10,0	14,3	7,9	2,0
SLX + Proof 3D	8,5	11,9	9,2	2,0
ShowFlow	7,0	11,2	28,2	1,5

Figure 7: Parameters of Google Search Results of Different Simulation Software (Dias et al., 2016)

DES Tools	#37 youtube.com (TV)	#38 linkedin.com (TV)	#39 facebook.com (TV)	#40 twitter.com (TV) (New!)	#41 plus.google.com (TV) (New!)
Weight	*1*	*2*	*3*	*1*	*1*
Average	*5,0*	*10,1*	*9,2*	*2,3*	*1,8*
Arena	15,0	78,7	17,5	2,8	3,5
ProModel	6,5	7,1	13,4	2,5	4,0
FlexSim	13,4	10,1	27,0	5,8	4,8
Simul8	4,8	14,0	17,5	7,1	3,1
WITNESS	11,4	11,1	15,6	4,8	2,0
ExtendSim	5,3	20,6	3,0	1,0	0,0
Simio	3,1	6,1	18,1	3,3	1,8
Plant Simulation	10,9	4,3	16,6	4,6	3,1
AnyLogic	1,7	4,0	3,0	1,7	2,5
SIMPROCESS	0,0	4,4	0,0	0,0	0,0
AutoMod	1,9	7,2	0,0	0,0	0,0
Micro Saint	0,0	3,2	0,0	0,0	0,0
QUEST (Delmia)	8,0	2,5	9,7	1,3	1,8
Enterprise Dynamics	3,7	6,8	10,6	2,2	1,8
ProcessModel	5,6	3,8	11,7	2,8	3,3
SimCAD Pro	3,1	3,2	10,3	3,3	1,9
GPSS World	1,0	0,0	0,0	0,0	0,0
SLX + Proof 3D	0,0	4,0	0,0	0,0	0,0
ShowFlow	0,0	0,0	0,0	0,0	0,0

Figure 8: Social Networks Parameters of Different Simulation Software (Dias et al., 2016)

Figure 8 represents the social network parameters of various simulation software and Figure 9 shows the simulation software reviews.

DES Tools	#10	#11	#12	#13	#14	#15	#16	#17	#18	#19	#20	#21	#22	#23	#24	#25	#26	#27	#28	#29	#30	#31	#32	#33	#34	#35	#36
	Mustafee 2007 "A GRID COMPUTING FRAMEWORK FOR	Abu-Taieh, 2007: CSP - COMMERCIAL SIMULATION PACKAGES.	VIVACE review 2004 Kim et.al "TECHNIQUES TO	SimulationTools.bib, 2010 http://www.idsia.ch/~andrea/sim/simlang.html	ORMS Survey 2009	WSC 2010 sponsorship	Systemflow list 2009 (http://www.systemflow.com/software_list.htm)	Google Directory www.google.com/Top/Scie	Wikipedia - List of discrete event simulation software http://en.wikipedia.org/wiki/	ORMS Survey 2003	PMC short list (2010)	www.averill-law.com/simulation-training-software.htm	SimServ WhitePaper (2004) Jaroslaw Chrobot	IIE Exhibitors (2011) (Institute of Industrial	Simul8Site (2006)	WSC 2005 sponsorship	Solution Simulation (2004)	Hlupic, 2000	Babulak 2008	Pemberton Cyrus 2004 Simulation Software http://pt.scribd.com/doc/38	Edwin Valentin (2002)	(Klingstam and Gullander, 1999)	(Pérez et al., 2013)	(Jadrić et al., 2015)	(Pezzotta et al., 2013)	(Vieira et al., 2014)	(Terzi and Cavalieri, 2004)
	3	2	2	3	4	3	2	2	2	1	2	1	1	2	1	1	1	1	2	1	1	2	3	1	1	4	1
Arena	2,2	2,9	3,5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
ProModel	2,1	2,3	3,1	1	1	1	1	1		1	1	1	1	1	1	1		1		1		1	1				
FlexSim	0,6	2,9	2,5	1	1	1	1			1		1	1	1		1	1	1		1			1				
Simul8	4,1	2,7	2,2	1	1	1	1	1	1	1	1	1	1			1	1	1	1	1							
WITNESS	3,2	2,3	3,3	1		1	1	1			1	1	1		1			1	1	1	1	1	1				
ExtendSim	2,6	2,0	3,2	1	1	1	1	1		1		1	1	1	1	1						1	1	1			
Simio				1	1	1		1	1														1			1	
Plant Simulation	1,9	2,0	1,0	1	1	1	1		1	1		1	1				1				1		1		1		
AnyLogic	2,7	3,2	2,1	1	1	1	1	1	1	1						1	1						1				
SIMPROCESS	2,7	2,3		1			1	1		1		1			1			1									
AutoMod	1,3	3,2	2,4	1		1	1			1	1	1	1		1	1	1		1	1	1	1					1
Micro Saint	1,3	1,2	1,0	1	1		1			1		1	1			1				1		1					
QUEST			3,4	1			1				1	1	1		1		1					1					
Enterprise Dynami	2,1	2,3	2,3	1			1	1	1	1	1		1		1	1		1			1		1				
ProcessModel	0,6		1,0							1		1			1												
SimCAD Pro	1,3	2,7	1,0	1	1			1	1	1				1			1										
GPSS World		2,0							1	1					1			1									
SLX + Proof 3D			1,0	1	1		1	1	1			1				1											
ShowFlow	0,6	2,1	1,0	1	1			1		1			1					1			1	1					1

Figure 9: Parameters of Selected Reviews of Different Simulation Software(Dias et al., 2016)

2.2 SIMIO

SIMIO is an intelligent object-based simulation modeling framework used in manufacturing, healthcare, marketing, transportation, warehouse operations, and supply chains. Modelers create intelligent objects, which can then be reused in multiple modeling projects. Although the SIMIO framework is primarily concerned with object-based modeling, it also allows for the seamless integration of other modeling paradigms such as event, process, object, and agent-based modeling. Despite the fact that a number of products have been introduced to support an object orientation, many practitioners have chosen to stick with the process orientation. While the underlying modeling paradigm may be easier and less conceptual, the specific implementation may be difficult to comprehend or slow in implementation. This is similar to the difficulties encountered by the management strategy in deposing the event orientation (Pegden, 2008).

SIMIO has certain advantages compared to other simulation software in the era of discrete event simulation. the SIMIO framework is a visual object-oriented model-based structure, not just a collection of classes in an object-oriented programming language that can be used for simulation modeling. SIMIO's graphical modeling framework approves the fundamental principles of object-oriented modeling without the need for programming skills to add new items to the system. the template of it is domain agnostic, allowing objects to be constructed that support a wide range of application areas. SIMIO's process modeling features enable the development of new objects with dynamic response. It supports a variety of modeling paradigms and the framework allows for the modeling of both discrete and continuous systems, as well as the modeling of events, processes, objects, and agents. the SIMIO framework includes specialized features that directly support virtualization and finite capacity planning applications that fully leverage SIMIO's general modeling capabilities (Pegden, 2008).

2.3 SIMULATION MODELING IN THE SUPPLY CHAIN OF A RESTAURANT

A number of simulation modeling techniques have been used in the area of supply chain management and logistics, but most of these techniques have been used in isolation (Mustafee et al., 2015). Theory of constraints along with simulation modeling can be a great tool for scheduling the proper utilization of the workstations (al Amin et al., 2018). Restaurant equipment, staffing levels, menu selections, and customer order mix all interact in complex ways in today's restaurants. Evaluating how changes will integrate into this complex system is frequently a difficult task. Small changes can make a big difference. Fast-food systems, in contrast to manufacturing systems, are highly labor-intensive. Furthermore, demand is typically intermittent and non-uniform. the majority of sales occur during peak hours. the fast-food industry is highly competitive, and service and production facilities must be well-designed to handle peak demand. Computer simulation allows for an accurate evaluation of changes in the restaurant without disrupting normal day-to-day operations (Kharwat, 1991).

2.4 KEY PERFORMANCE MEASURES OF A RESTAURANT'S SUPPLY CHAIN SIMULATION MODEL

1. **Order Statistics**
   - How many orders are completed
   - Average time each order is completed
   - Average time each order is delivered
   - Average no of orders processed at a time
2. **Process Statistics**
   - Count of Executions per Station
   - Total Late Orders
   - Avg. Time Orders are Late
3. **Worker Statistics**
   - Utilization of each server
4. **Food Statistics**
   - Current stocks in Inventory
   - Average time for Units to Restock

2.5 PROBLEM STATEMENT

the COVID-19 crisis has already altered food systems by affecting demand, food supply, and ability to produce and distribute food, as well as consumer behavior such as panic buying, shortages in certain food groups, and food waste and loss. As a result, COVID-19 has an impact on all four aspects of food nutrition and security (availability, stability, access, and utilization) (Boyacı-Gündüz et al., 2021). In this adverse situation, it is very tough for the business owner to continue their business. We have studied the case of a small pizza restaurant in day-to-day supply chain operation, supplier availability, supplier information and optimal resource allocation in each workstation. Labor shortages and longer lead times from suppliers plagued the restaurant. They also experienced a significant increase in demand for delivery orders while decreasing carryout orders. We need to recommend the optimal resource requirement in terms of employee crisis, cost increase and how to answer the what-if scenarios. Also, a supply chain cost estimation optimization model needs to be developed during the disruption period.

2.6 THE RESTAURANT PROCESS

the restaurant's supply chain simulation model has been built using the simulation software SIMIO 14. the sequence of operations performed to complete a customer order was built using discrete event modeling. the term discrete refers to how discrete event modeling skips from one event's time to the next. Figure 10 depicts the sequence of events that the order must go through before being handed over to the customer. Within the restaurant, processes include taking orders, preparing orders, cooking orders, packing orders, and serving or delivering to the customers. Figure 11 shows the reflected sequence in SIMIO software.

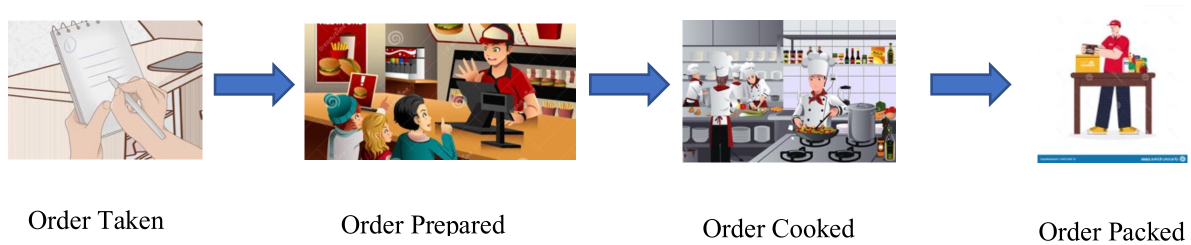


Figure 10: The Restaurant Process (Getty Images, n.d.)

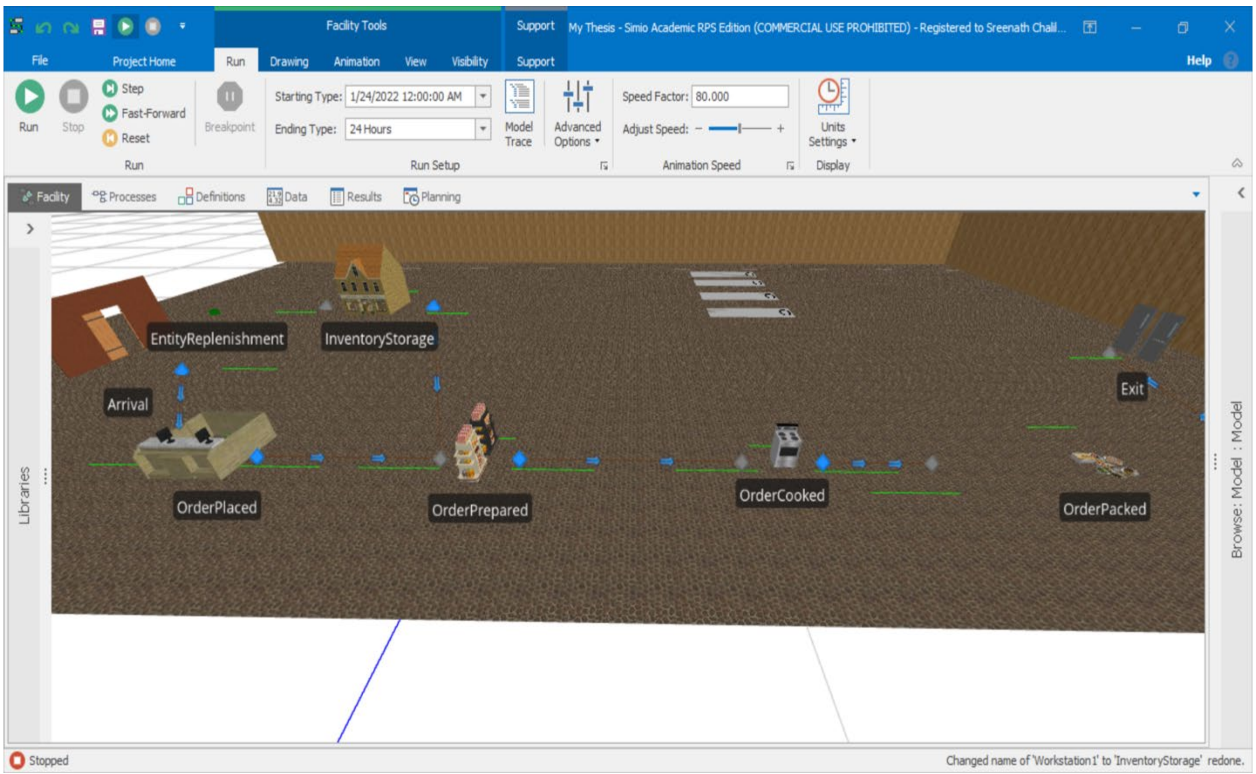


Figure 11: The Restaurant Process in SIMIO Software

2.7 MODELING APPROACH IN SIMIO

SIMIO interface has libraries of different objects such as Source, Server, Sink, Workstation, Resource, Path etc. Most used objects in a simulation model are the Source, Server, Path and Sink.

Source: A source object is used to generate entities of a specified type. In this research source is named as 'Arrival' which has Entity type, Arrival mode, Entities per arrival parameters. Our entity type is order, Arrival mode has four options which are Interarrival Time, Time varying Arrival Rate, On Event and Arrival Table. As Time varying arrival rate is used in this research, a rate table was developed to declare the rate of arrivals. Figure 12 shows a snapshot of SIMIO model of source and properties

Server: A server object is used to represent a processing location with limited capacity. Server

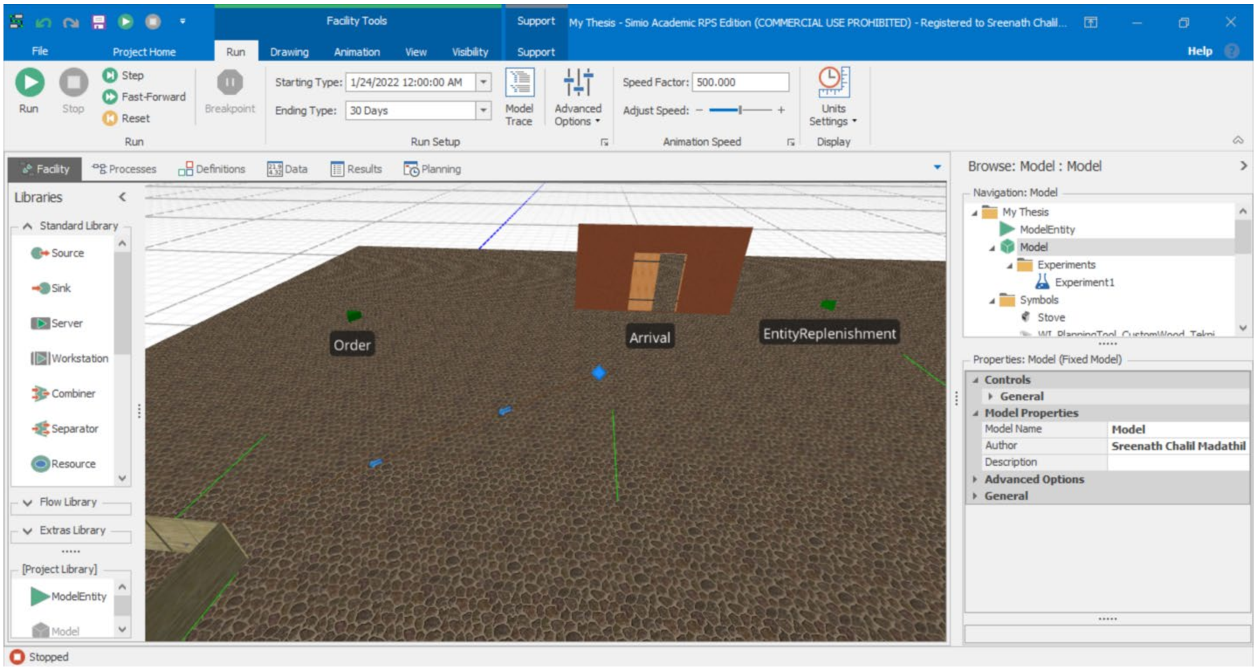


Figure 12: Animated Source and it's Properties

operations can be modified as either a processing time or a sequence of tasks. We have used four servers here i.e., OrderPlaced, Order Prepared, OrderCooked and OrderPacked. For each server, there are some parameters. Capacity Type, Ranking Rule and Process type are some common ones. Moreover, any add-on process can be added to the server. People can use capacity type as fixed or Workschedule. Ranking rule can be used First in First Out (FIFO), Last in First Out (LIFO), Smallest Value First (SVF) or Largest Value First (LVF). Process type can be used as task sequence and specific time. For specific time, processing time need to be mentioned.

For the Order Placed server, WorkSchedule capacity type is used. Fixed capacity type can also be used but in our modeling based on the data, workschedule is suitable. First in First Out (FIFO) is used as the ranking rule. Specific time is used as process type and pert distribution is used for processing time. Other properties are kept as default. Figure 13 illustrate the animated order placed server with properties

For the Order Prepared server, WorkSchedule capacity type is used. Fixed capacity type can also

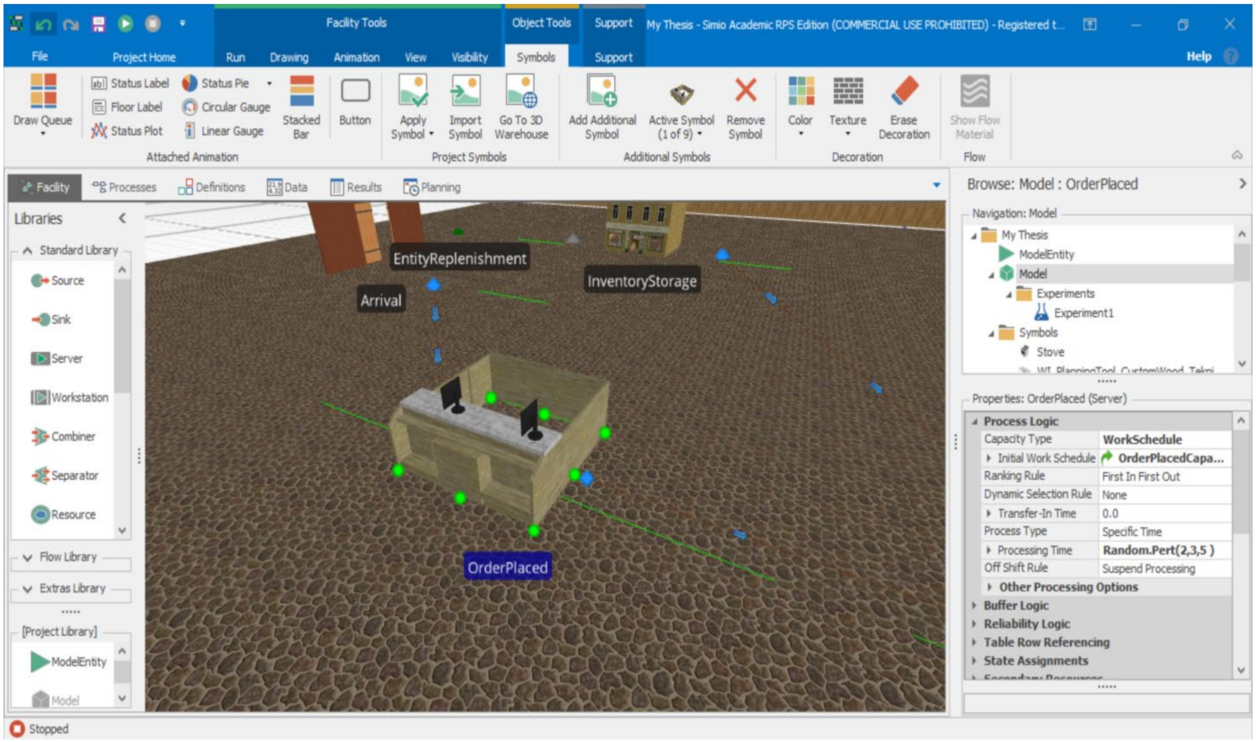


Figure 13: Animated Order Placed Server with Properties

be used but in our modeling based on the data, workSchedule is suitable. First in First Out (FIFO) is used as the ranking rule. Specific time is used as process type and pert distribution is used for processing time. Other properties are kept as default. Figure 14 shows the simulation model's sever.

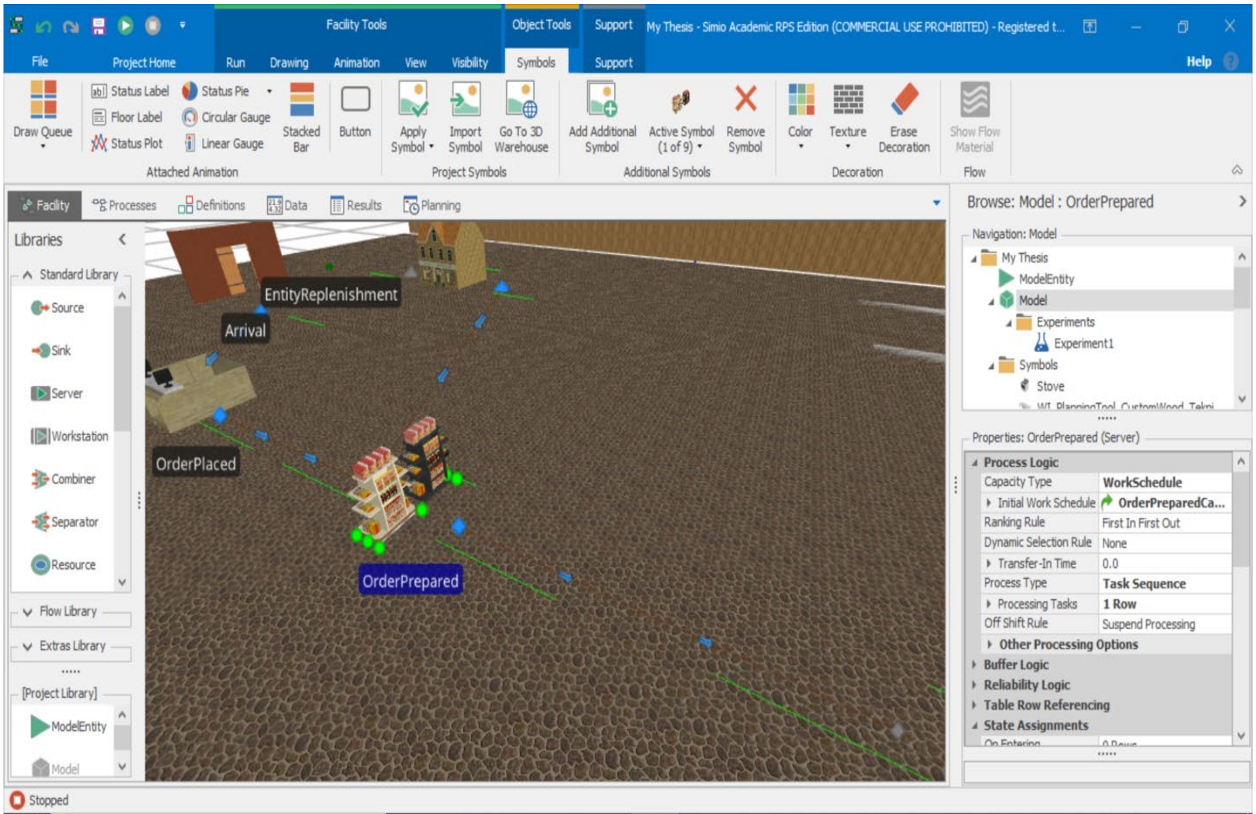


Figure 14: Animated Order Prepared Server with Properties

For the Order Cooked server, Fixed capacity type is used. First in First Out (FIFO) is used as the ranking rule. Specific time is used as process type and pert distribution is used for processing time. Other properties are kept as default. Figure 15 shows the order cooked server.

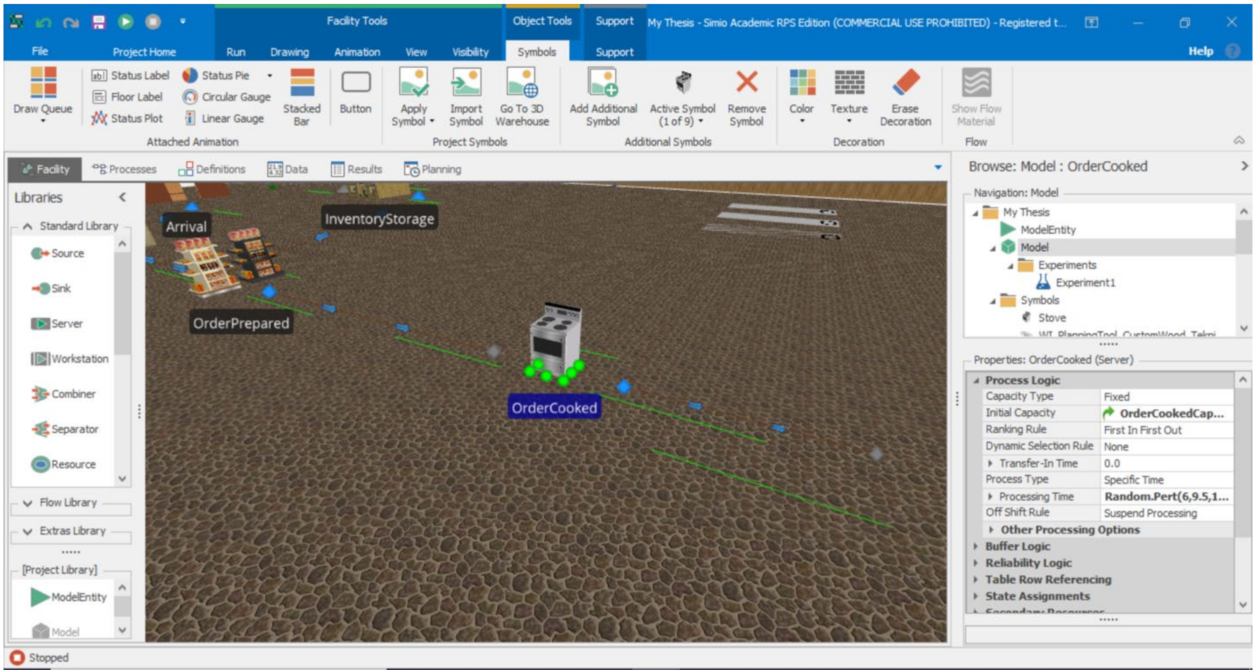


Figure 15: Animated Order Cooked Server with Properties

For the Order Packed server, WorkSchedule capacity type is used. Fixed capacity type can also be used but in our modeling based on the data, workSchedule is suitable. First in First Out (FIFO) is used as the ranking rule. Specific time is used as process type and pert distribution is used for processing time. Other properties are kept as default. Figure 16 demonstrate the order packed server.

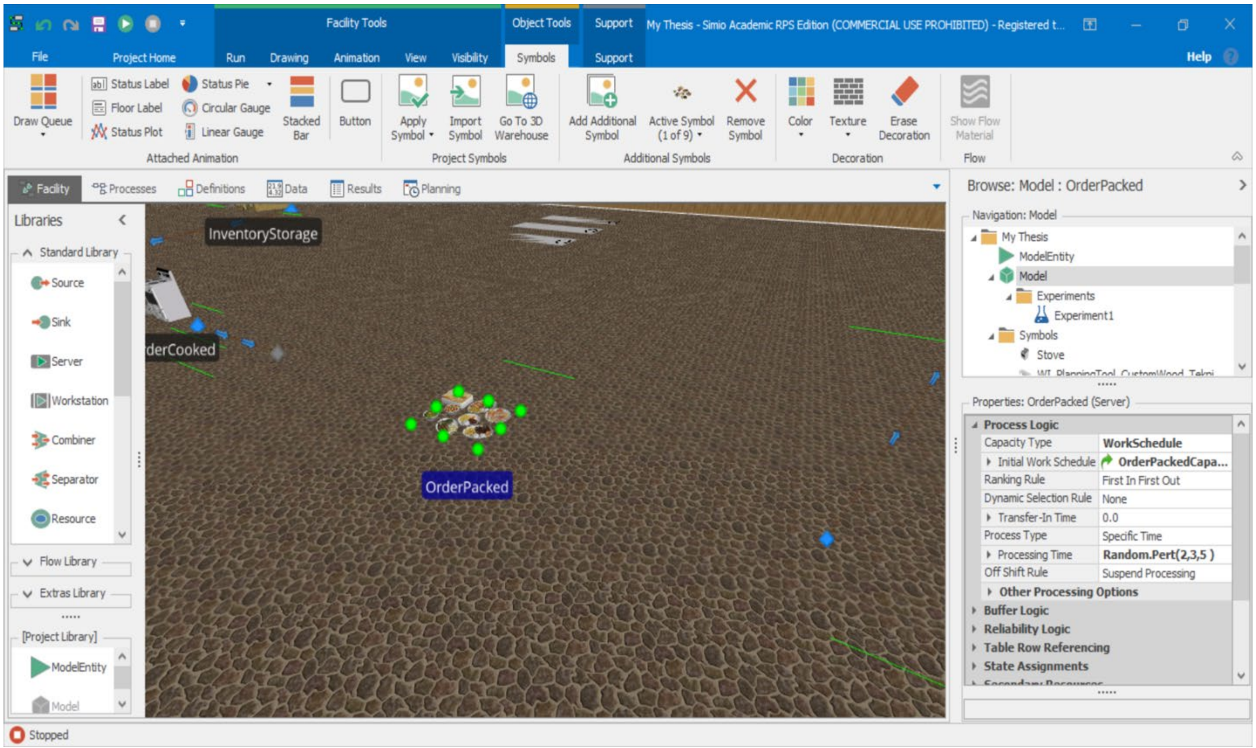


Figure 16: Animated Order Packed Server with Properties

Sink: A sink is used to destroy entities that have finished processing in the model. All the properties here kept as default. Figure 17 shows the sink and its properties.

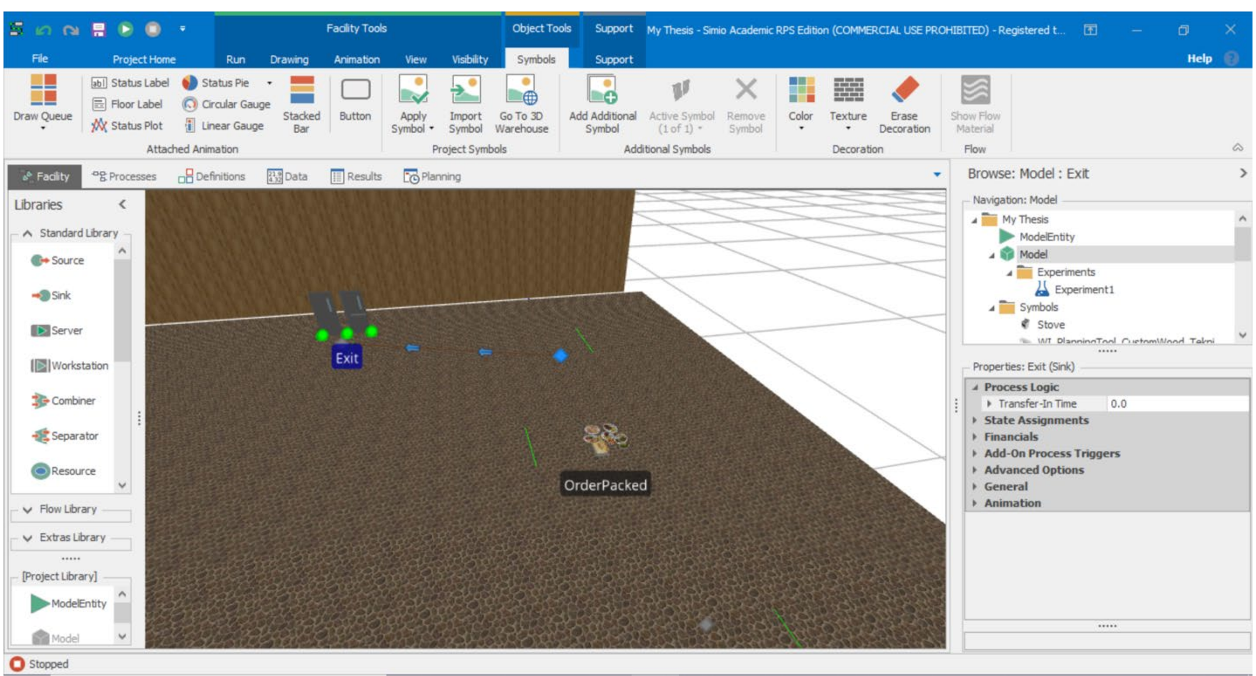


Figure 17: Sink and it's Properties

First, entities are generated by the source, which is the process's starting point. Entities move through the system; in this case, they represent customer orders. the source specifies how many orders should be generated as well as the precise arrival times and quantities. We used an arrival table with the number of orders per hour because the restaurant is busiest during lunch and dinner and has set working hours. Table 1 contains the relevant data. In the modeling, the ‘arrival’ is the source object. For the arrival mode logic of the source, we have used ‘Time Varying Arrival Rate’ which was connected to a rate table which is shown in Table 1. We can see from Table 1 that the starting point of the simulation I mean the first 10 hours has no orders as the restaurant opens at 10 am.

Table 1: Carry Out Arrival Times

Start	***End***	***Value***
10:00:00 AM	11:00:00 AM	3
11:00:00 AM	12:00:00 PM	2
12:00:00 PM	1:00:00 PM	6
1:00:00 PM	2:00:00 PM	7
2:00:00 PM	3:00:00 PM	8
3:00:00 PM	4:00:00 PM	14
4:00:00 PM	5:00:00 PM	15
5:00:00 PM	6:00:00 PM	10
6:00:00 PM	7:00:00 PM	11
7:00:00 PM	8:00:00 PM	9
8:00:00 PM	9:00:00 PM	7
9:00:00 PM	10:00:00 PM	5
10:00:00 PM	11:00:00 PM	3

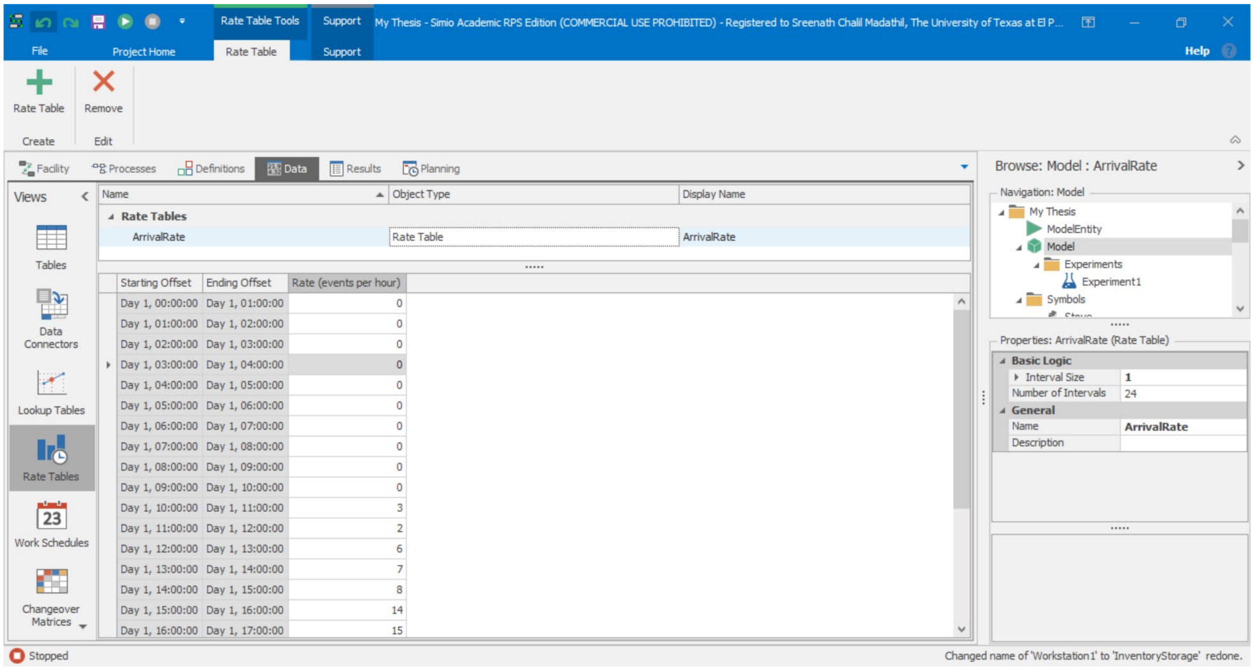


Figure 18: Restaurant's Discrete Modeling Process for Carry Out Orders

Figure 18 illustrates the discreet modeling process of the carry out orders. the orders enter the first step, "OrderPlaced" where the employee takes the order and sends it to the kitchen. the duration of this process is represented by the pert distribution, which is a continuous distribution with three inputs, Minimum, Most Likely, and Maximum (pert (min, mode, max)). It was noted that 80% of customers already knew their order. In comparison, the other 20% had to be assisted with their options which delayed the process. It was set up by an Add on Process which is shown in Figure 19. Each server is represented as a work processing station.

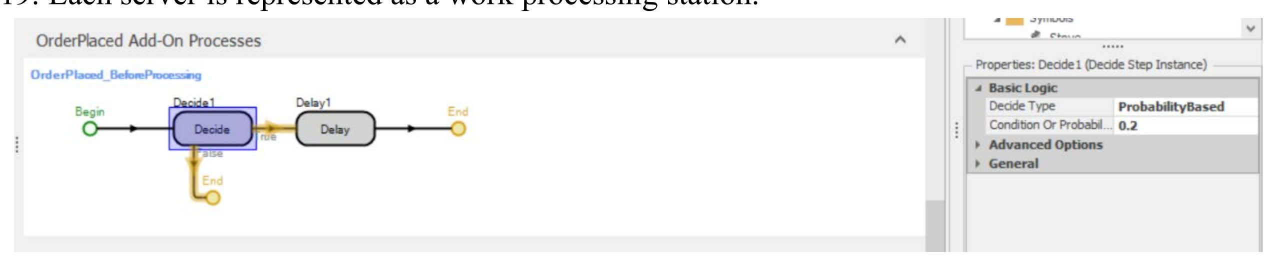


Figure 19: Add on Process for the customers who needs help with the order

Based on multiple conditions, the orders can then be delayed or sent to "OrderPrepared." Orders can only enter the restocking delay if any of the inventory products have reached zero. Orders in this stage can wait until the product is restocked or canceled. the time it takes for the supplier to arrive at the restaurant will determine the waiting time. This delay does not necessitate the use of any employees. Assume that none of the products have an inventory of zero. Orders will be routed

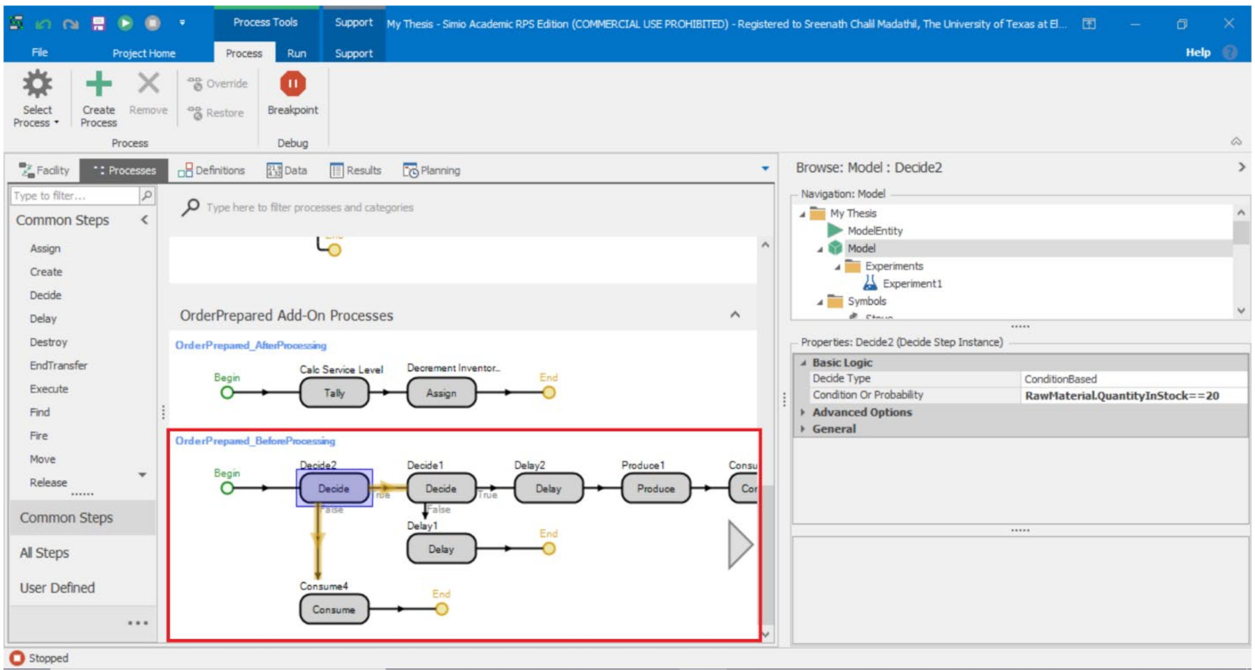


Figure 20: Add-on Process when Inventory is Close to Zero

to "OrderPrepared" in that case. Figure 20 is showing the actual representation.

Once the order has been prepared, it is sent to the "OrderCooked" server, where the cooking process begins. This server has a capacity of 6 orders cooking at once. If the capacity is full, orders will be queued until the capacity becomes available. the orders are then packed and handed over to customers before exiting through the "Sink" block for disposal.

2.7.1 VARIABLES

From the definitions tab, we have declared necessary variables.

Elements: An element is a part of a model with particular inherent attributes, states, and behavior. Process phases frequently reframe elements. the.NET framework allows users to add their own unique custom elements and associated steps.

- **Inventory Elements:** We have used an inventory element named 'Raw Material Inventory' where the initial quantity has been set as 50. Review period has been taken as continuous and replenishment policy has been set as Reorder Point/Reorder Qty. Our reorder point is 20 and reorder quantity is 30 in the modeling it is shown in below Figure 21.

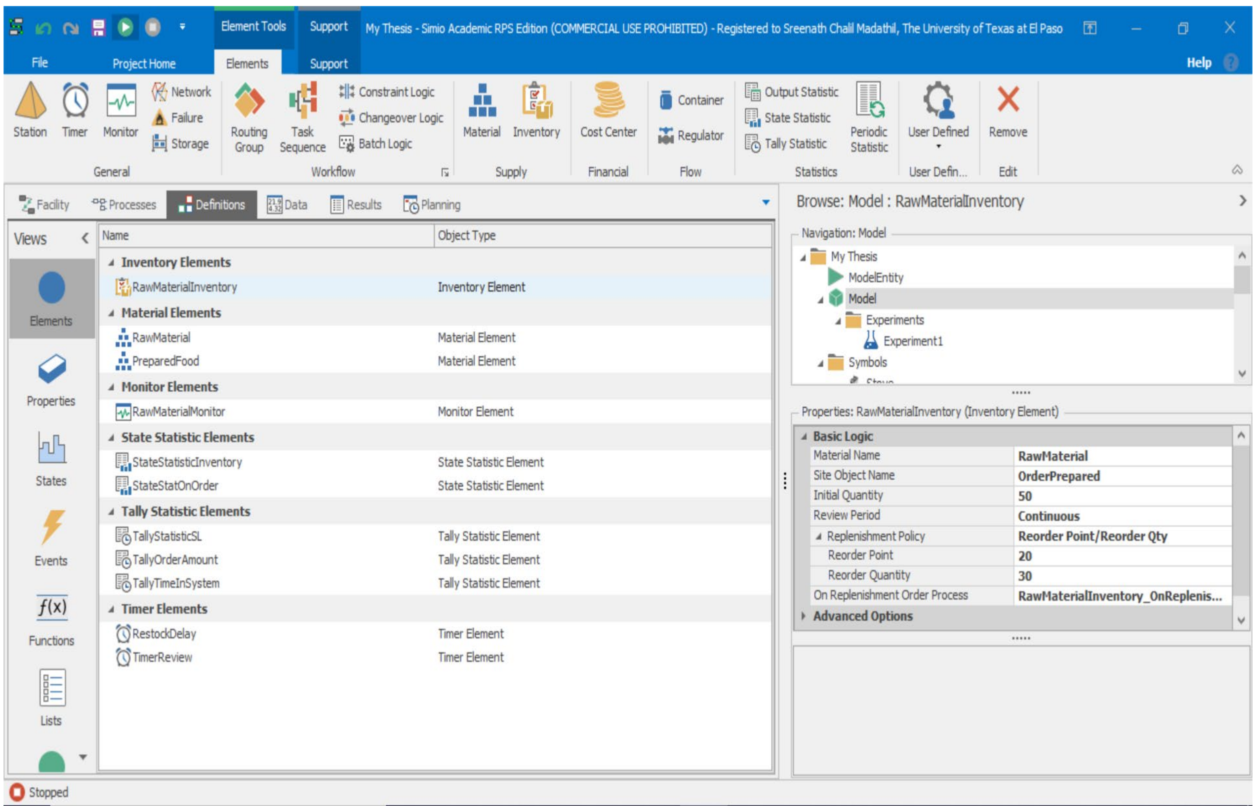


Figure 21: Inventory Elements and it's Properties

- **Material Elements**: Two material elements have been used. For the material element named as 'Raw Material', Location based Inventory is set as TRUE and it is connected with OrderPrepared server which is shown in Figure 23.

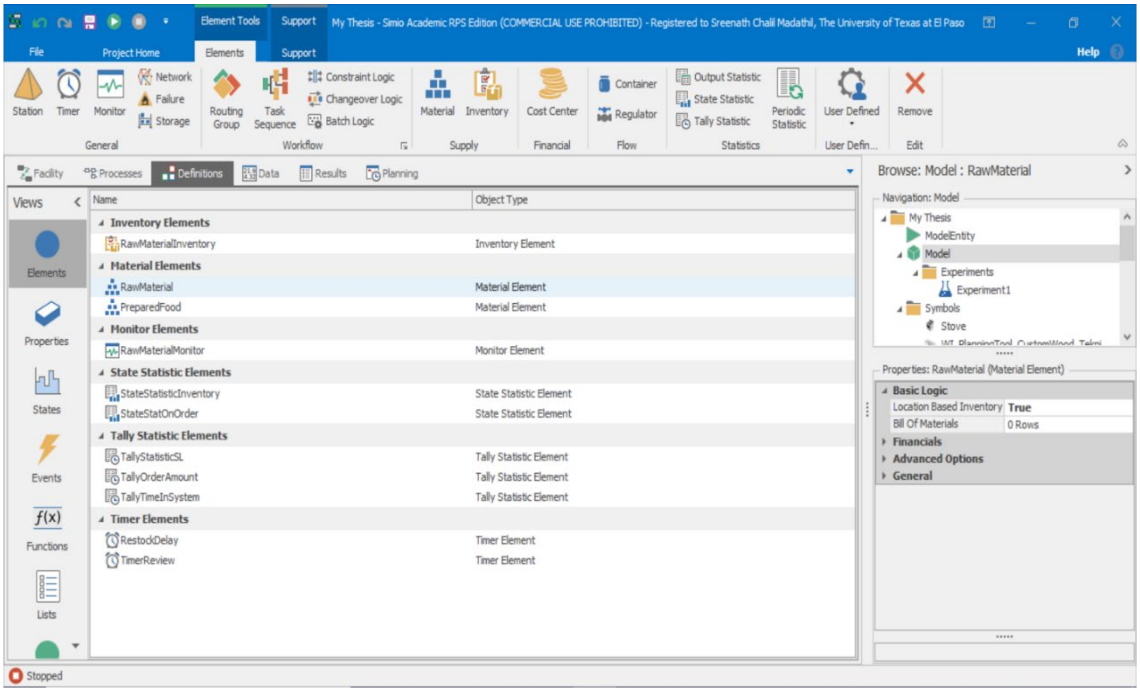


Figure 23: Material Elements and it's Properties

- **Monitor Element:** One monitor element 'Raw Material Monitor' is used whose monitor type is crossing state change and crossing direction is negative. Figure 22 shows the monitor element.

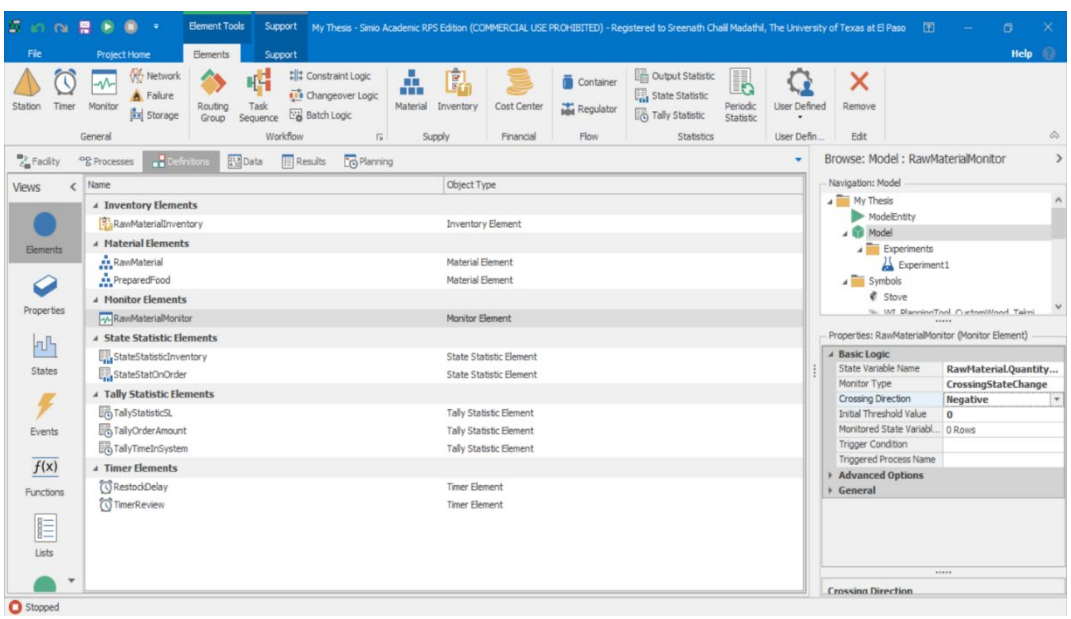


Figure 22: Monitor Elements and it's Properties

- **State Statistic Element:** Two state statistic element is used; one is state statistic inventory whose state variable is ‘Current Inventory’ and the other one is state stat on order whose state variable is on order which is shown in Figure 24.

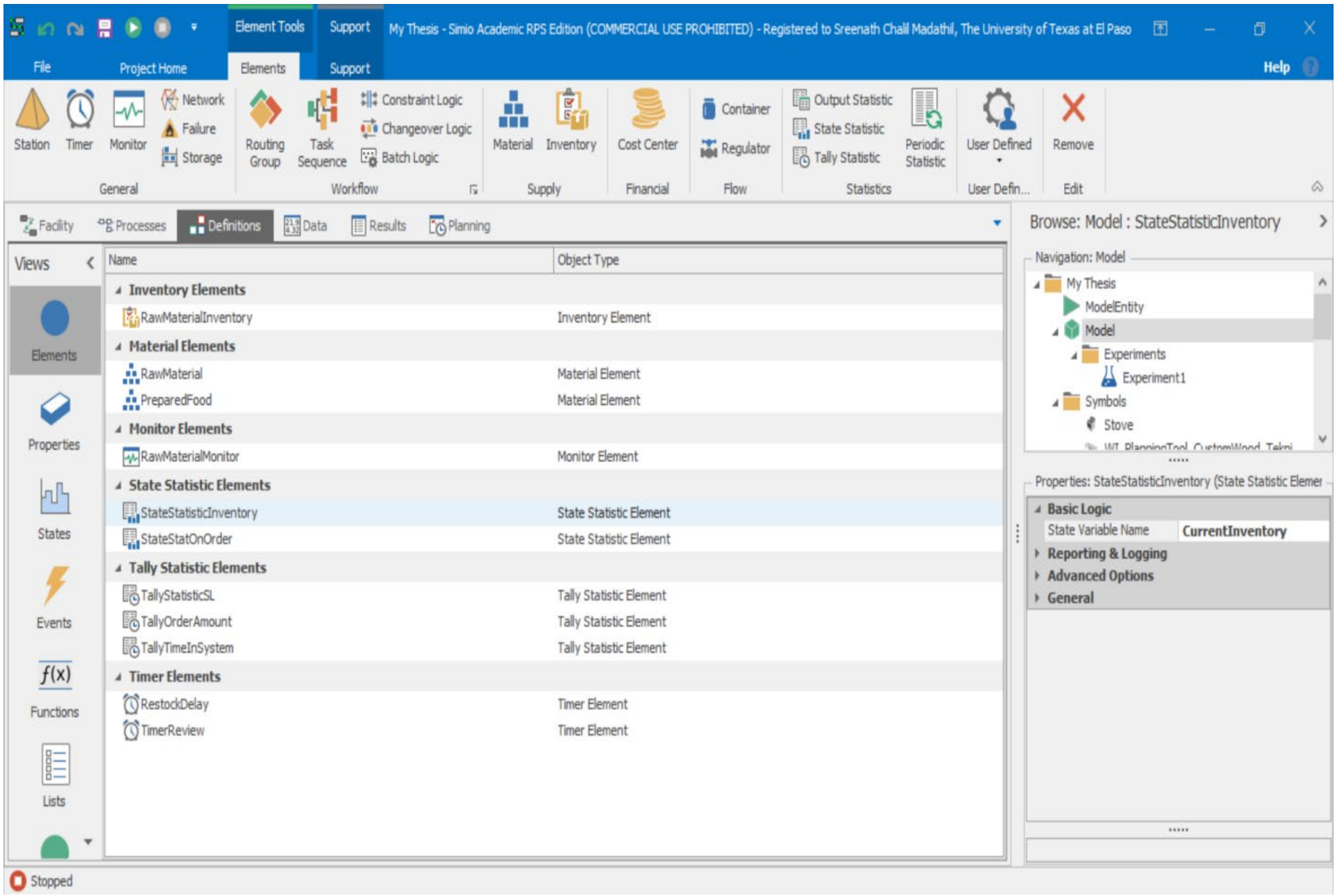


Figure 24: State Statistic Inventory and it's Order

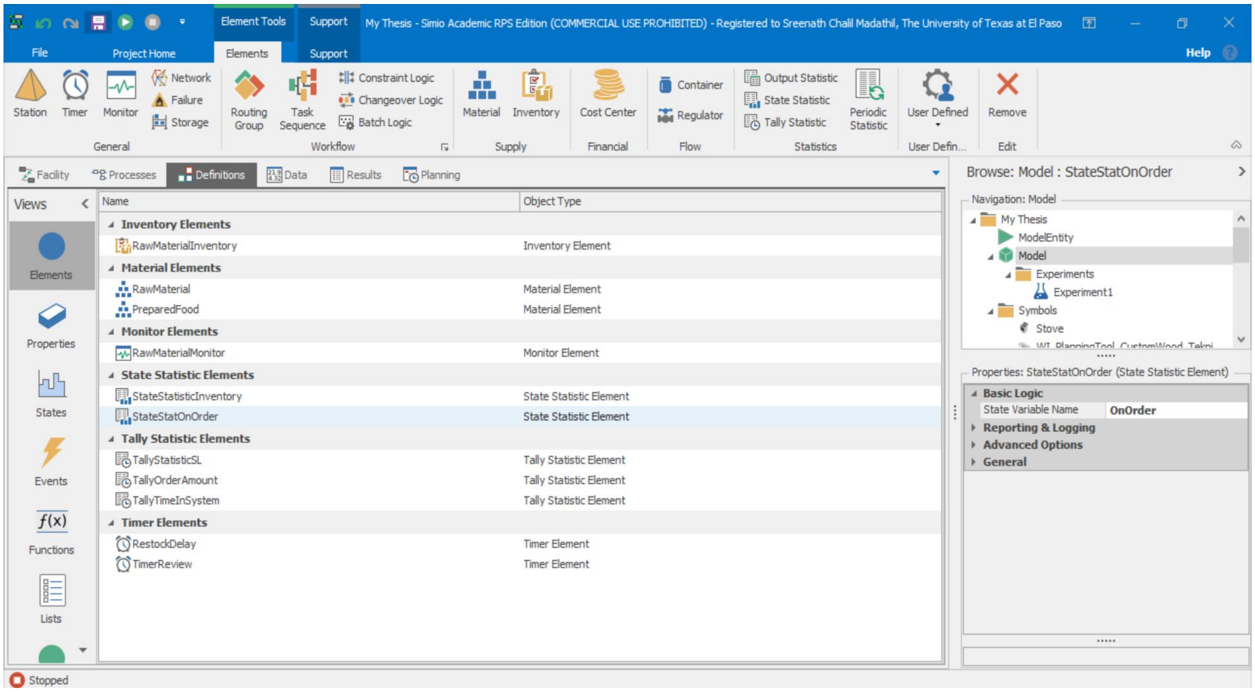


Figure 25: State Stat on Order and it's Properties

- **Tally Statistics Element:** Three Tally Statistics Element were used to calculate the Service Level, Order Amount and Time in System shown in Figure 26.

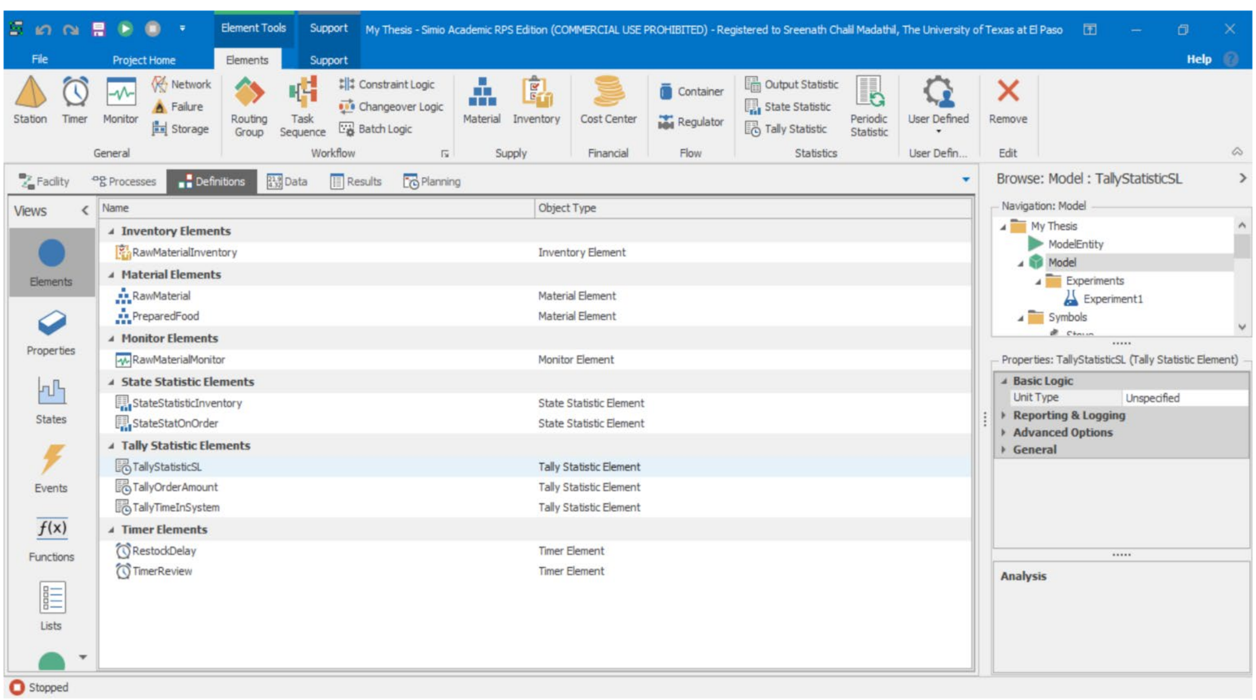


Figure 26: Tally Statistic Element and it's Properties

- **Timer Elements:** Two timer elements were used. They are Restock Delay and Time Review. Time interval of ‘Restock Delay’ timer element has been set as 10 minutes and time offset has been set 0. On the other hand, time offset and time interval of ‘Time Review’ has been set as a reference property named ‘Review Period’ shown in Figure 27.

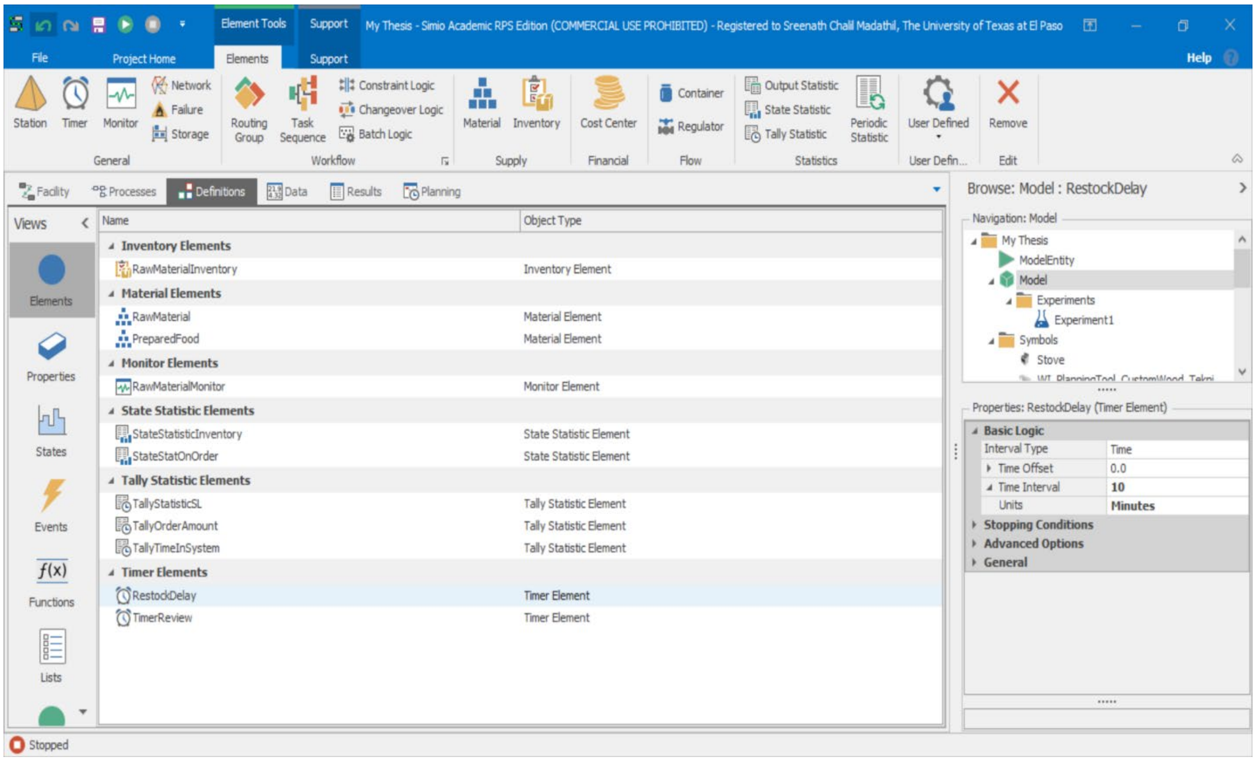


Figure 27: Restock Delay Time Element and it's Property

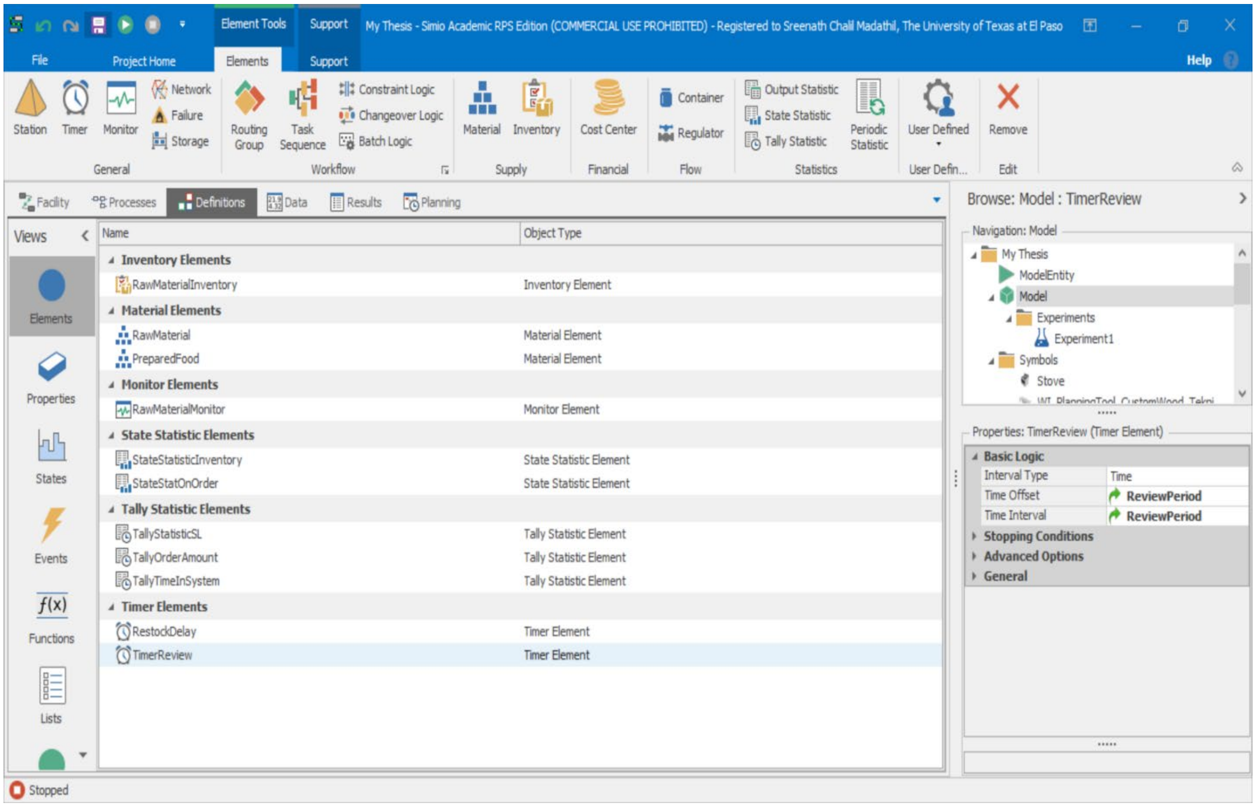


Figure 28: Time Review Time Element and it's Property

2.7.2 RESOURCE SCHEDULING

the model is launched with a typical day's processing times and number of incoming orders. Each processing station has four shifts in a typical day. the ideal due time for carryout orders on a typical working day is 40 minutes, and the scheduled time for deliveries is 55 minutes. the orders are routed to the "OrderPlaced" server, where they are processed in pert (2, 5, 3) minutes. the order-taking process has one employee for shifts one, two, and four, and two employees for shift three. If the inventory reaches zero, half of the customers will cancel, while the other half will wait until it is restocked. Otherwise, the orders will be routed to the next station, "OrderPrepared" and processed in pert (2, 5, 3.5) minutes. the orders are then routed to the next station, "OrderCooked" where they are completed in pert (6, 12, 9.5) minutes. the orders are then prepared in the following step, "OrderPacked," which takes approximately (2, 5, 3) minutes. Table 2 provides a summary of the employee shifts.

Table 2: Employee Shifts for Each Server

Shift	Order Placed		Order Prepared		Order Packed	
Shift 1	10:00 - 14:00	1	10:00 - 14:00	1	10:00 - 14:00	1
Shift 2	14:00 - 16:00	1	14:00 - 16:00	1	14:00 - 16:00	1
Shift 3	16:00 - 22:00	2	16:00 - 21:00	2	16:00 - 22:00	1
Shift 4	22:00 - 23:00	1	21:00 - 23:00	1	22:00 - 23:00	1

2.7.3 DELIVERY TO CUSTOMERS

If the orders are requested for delivery, a few more steps must be added to the process. After the order has been packed, a delivery driver or resource is commanded to grab a truck in the "OrderPacked" server and drive 25 mph to the customer from the restaurant. This has one employee or driver for the truck for each shift. This process happens with a pert distribution of (3,6,5) minutes. Once the driver arrives, he unpacks and hands the order to the customer. Finally, the driver navigates back to the restaurant to a specific location. As it is not much in our output of the model, we have ignored the delivery and confined the model just to serving.

2.7.4 INVENTORY AND SUPPLIERS

the restaurant's supply chain has two different suppliers: Supplier A and Supplier B. Supplier A is responsible for sending all the ingredients to the restaurant, and Supplier B usually works as a standing supplier or safety supplier when supplier A runs out or is in the disruption period. All products in stock decrease at a daily usage rate, suppose the supply of any product reaches a low number 20. In that case, it will send an order of 30.

3. COST ESTIMATION OPTIMIZATION MODEL DEVELOPMENT

We have seen significant changes in fill rate due to stockout time. in covid 19 period, the supplier was suffering to supply product on time and it eventually hurt many companies. especially a lot of home delivery orders were not possible to deliver to the customer due to the shortage of supply. in essence, a well-established and robust supply chain strategy would allow a company to deploy the associated contingency plans efficiently and effectively in the event of a disruption. as a result, having a strong supply chain strategy can help a company become more resilient (tang, 2006). Figure 29 shows the safety supplier is supply chain disruption.

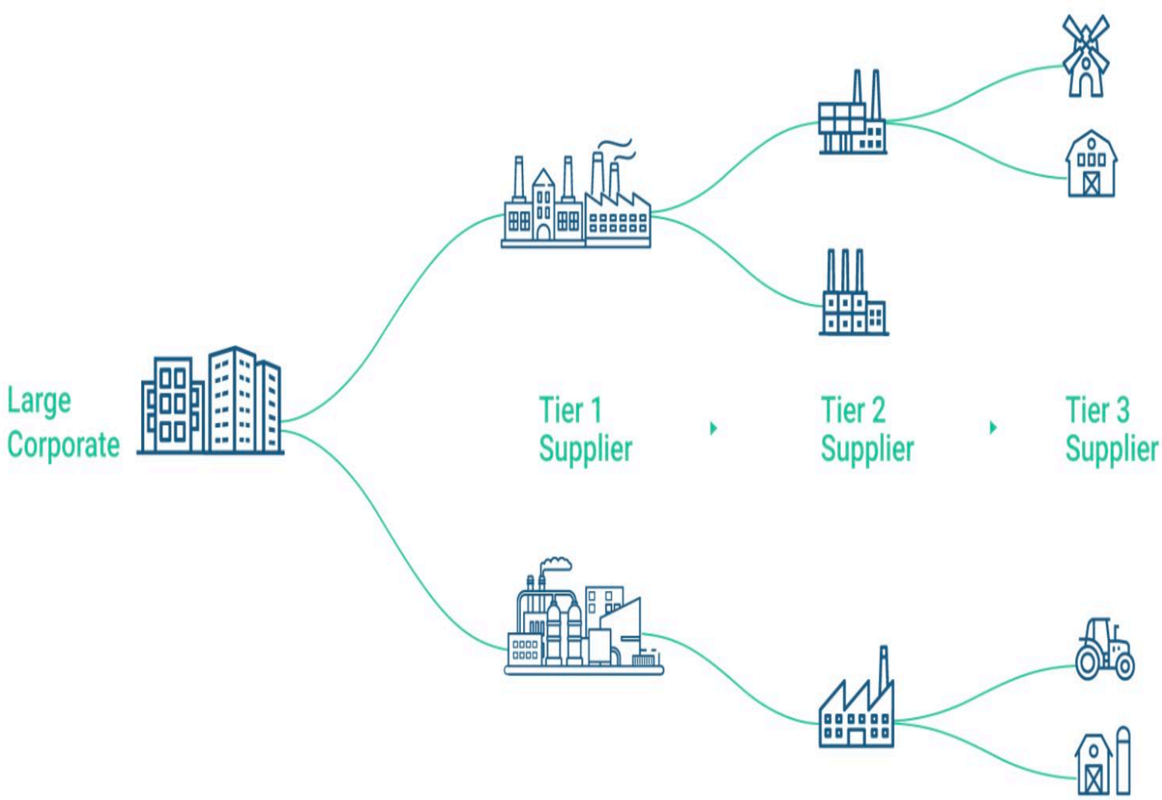


Figure 29: Different Tier of Suppliers in Disruption

There are a lot of strategies previously used for mitigating supply chain disruptions. Different strategies suits for different types of industries. the following robust strategies can be used to manage the disruption for food industries or small types of restaurants.

a) Safety supplier: Safety supply options are a way to maintain supply during a disruption. the buyer enters into contracts with safety suppliers, and the safety suppliers charge a reservation fee for registering any buyer to reserve a portion of supply at a fixed price that is less than the market price at any time or disruption period, but slightly higher than the price of regular supply. the buyer must also pay a penalty for unused backup units.

b) Market price purchase: If there is no option other than the market price purchase, then the buyer needs to buy it by paying the market price on that day.

Based on that concept we have proposed a cost estimation optimization model along with the probable constraints.

Notations

the mathematical formulation uses the following notations:

Sets

I Set of potential top level suppliers, i = 1, 2, . . . , I

J Set of potential safety suppliers, j = 1, 2, . . . , J

N Set of potential recovery rate levels at primary suppliers, n = 1, 2, . . . ,N

L Set of potential warning capability levels at primary suppliers, l = 1, 2, . . . , L

S Set of potential disruption scenario, s = 1, 2, . . . , S

Parameters

f_i Cost of agreement with top level supplier i

p_i Purchasing price from top level supplier i

m_s Spot price of that particular day in market under scenario s

p'_j Purchasing price from safety supplier j

h_j Per unit capacity holding cost of safety supplier j

c_i Capacity of top-level supplier i

D Demand

y_s Per unit penalty cost of unfulfilled order under scenario s

P_i^n Recovery rate of top-level supplier i at level u

r_i^n Cost of upgrading recovery rate to level u for top-level supplier I

Γ_i^l Warning capability of top-level supplier i at level l

w_i^l Cost of upgrading warning capability to level l for top-level supplier i

ρ_i Probability of top-level supplier i being disrupted

q_s Probability of disruption scenario s

c'^s_i the capacity (in percentage) top level supplier i can provide in disruption scenario s

f_i^s, 1 if primary supplier i is affected by disruption scenario s; 0 otherwise

P^{max} Highest delay time for receiving order from disrupted top level supplier i

M A big number

Variables

x_i Binary variable equals 1 if top-level supplier i is selected, 0 otherwise.

y_i Amount ordered from top-level supplier i

a_j the amount of capacity is reserved at safety supplier j.

b_i^n Binary variable equals 1 if top-level supplier i is at recovery level u, 0 otherwise.

g_i^l Binary variable equals 1 if top-level supplier i is at warning level l, 0 otherwise.

Variables for disruption scenarios

d_s Spot market purchase

d_j^s Capacity used of safety supplier j for covering excess demand in scenario s.

s_s Shortage in disruption scenario s

t_i^s Time consumed by disrupted top-level supplier i in scenario s

Model Formulation

Contract Signing Cost of top-level supplier = $\sum_i^I f_i x_i$

Purchasing cost from top-level suppliers = $\sum_i^I p_i y_i$

Holding cost of safety supplier = $\sum_j^J h_j a_j$

Cost of enhancing recovery rate for top-level supplier = $\sum_i^I \sum_n^N r_i^n b_i^n$

Cost of enhancing warning capability for top-level supplier = $\sum_i^I \sum_l^L w_i^l g_i^l$

Probability of each disruption scenario = $\sum_s^S q_s$

Purchasing cost with the safety supplier+ spot purchasing cost+ penalty cost for an unfulfilled order=$\sum_j^J (p'_j d_j^s + m^s d_s + c'^s \eta_s)$

Objective Function

$$\text{Min } \sum_i^I f_i x_i + \sum_i^I p_i y_i + \sum_j^J h_j a_j + \sum_i^I \sum_n^N r_i^n b_i^n + \sum_i^I \sum_l^L w_i^l g_i^l + \sum_s^S q_s \sum_j^J (p'_j d_j^s + m^s d_s + c'^s \eta_s)$$

Constraints

1. Amount ordered from top-level supplier + Amount of safety supplier capacity used to satisfy excess demand in scenario s + Spot market purchase + Shortage in disruption scenario s is greater than or equal to total demand so $\sum_i^I y_i + \sum_j^J d_j^s + d_s + s_s \geq D$

2. the amount of quantity ordered from top-level suppliers does not exceed the top-level supplier's capacity so $y_i \leq (1- f_i^s)\, c_i^s x_i + f_i^s (c_i\, c'^s_i y_i + \sum_n^N t_i^s P_i^n)$
3. the total amount of quantity purchased from safety supplier is not greater than the amount of reserved capacity at safety supplier so $d_j^s \leq a_j$
4. the total time that is used for recovering the capacity of any top-level supplier to a particular level does not exceed the maximum delay time. the maximum delay time is defined by manufacturer based on their tolerance for sourcing beyond the due date so $t_i^s(1\text{-}\Gamma_i^l\ g_i^l) \leq P^{max}$
5. Total amount of recovered quantity at level by a top-level supplier i depends on the recovery rate level of that supplier so $t_i^s P_i^n \leq M\ b_i^n$
6. the amount of time that a disruption can be detected earlier (warning time) depends on warning capability level which is a function of supplier visibility so $t_i^s \Gamma_i^l \ \leq \mathrm{M} g_i^l$
7. the investment on the level of collaboration and visibility of a given top-level supplier is equal to zero if the contract with that supplier is not signed so $\sum_n^N b^S \leq x_i$ and $\sum_l^L g_i^l \leq x_i$ and $\sum_n^N g_i^s \leq x_i$
8. the contract, with only one top-level supplier, must be signed so $\sum_i^l x_i$=1

Assumptions

1. In the disruption period, safety suppliers are always ready to give support and continue to supply the predetermined amount.
2. the probability of disruption of the main supplier and safety supplier at the same time is not considered.
3. Main suppliers have different levels of recovery rates and buyers have different levels of warning capability.

4. Main suppliers can be fully or partially disrupted.
5. There is a specific time for a disrupted supplier to recover from disruption.
6. In the specific time of a disrupted supplier, the suppliers can face different levels of recovery rate and buyers have several levels of warning capability.
7. Any other strategy other than the discussed scenarios, will add extra cost in the disrupted period.

4. RESULTS

4.1 MODEL VALIDATION

A model should be created for a specific purpose or application, and its validity should be determined by that purpose. If the model's purpose is to answer a variety of questions, the model's validity must be evaluated separately for each question (Sargent, 1991). As previously discussed, several model parameters were changed to see if the model was working properly and could be used to find solutions. Firstly, in reality, the average time to complete an order is 40 minutes. In our modeling, when disruption probability is 1% it is 44.64 minutes which is very close to reality. the number of employees at each station within the restaurant was reduced, and it was discovered that the time it took to complete an order increased by about 10%. In the same form, the processing times for the stations inside the restaurant were increased by at least 4 minutes. Practically the utilization of the servers is 30% to 40%, in our modeling, it is also very nearby as well. So, the performance measurements of the current system through the modeling are very close to the data of real-life and it can be told that the modeling is very close to reality.

4.2 MODEL RUN AND RESULTS

the model was run for 30 days and the results are listed in Table 3.

Table 3: Performance Measurements for Current System

Key Performance Measure	***Value***
Average Order Completion Time	44.64 minutes
Average stockout time per month	621.54 minutes
Total Orders in a month	3020

Table 4: Utilization and Waiting Time of Each Server

Server	***Utilization***	***Waiting Time (Minutes)***
Order Placed	45.35%	8.21
Order Prepared	34.18%	1.11
Order Cooked	10.85%	0.003
Order Packed	40.60%	4.94

4.3 EXPERIMENTATION AND SCENARIO ANALYSIS

As we are interested to see the optimal resource allocation in different disruption probabilities, so we have conducted some scenarios and experimentations. All the scenarios have 5 replications without any warm-up periods and a 95% confidence level. We have used 3 disruption probability scenarios. First 8 scenarios were done for 1% disruption probability, scenario 9 to 16 were done for 100% disruption probabilities and scenarios 17 to 24 done for 10% disruption probabilities. we want to see the changes in service time meaning the time in system to complete an order in terms of best resource allocation and disruption probabilities.

4.3.1 DISRUPTION PROBABILITY 1%

Scenario 1:

1st scenario is as per the normal resources of the current system. Orders Placed capacity in normal time is 1 and in busy times 2; Order prepared capacity is remaining the same also; Order cooked capacity is traditionally 6 and Order packed capacity is keeping 1 all the time, we have got the following key performance measure at 95% confidence level.

Table 5: Key Performance Metrics of Scenario 1

Key Performance Measure	Value
Average Order Completion Time	44.64 minutes
Average stockout time per month	621.54 minutes

Scenario 2:

2nd scenario consists of Orders Placed capacity being dedicatedly 1 all the time; Order prepared capacity in normal times being 1 and in busy times 2; Order cooked capacity being traditionally 6 and Order packed capacity keeping 1 all the time, we have got the following key performance measure at 95% confidence level.

Table 6: Key Performance Metrics of Scenario 2

Key Performance Measure	Value
Average Order Completion Time	83.68 minutes
Average stockout time per month	621.54 minutes

Scenario 3:

3rd scenario consists of all the servers except Order cooked capacities being dedicatedly 1 all the time and Order cooked capacity is 5, we have got the following key performance measure at 95% confidence level.

Table 7: Key Performance Metrics of Scenario 3

Key Performance Measure	Value
Average Order Completion Time	181.6 minutes
Average stockout time per month	621.54 minutes

Scenario 4:

4th scenario consists of Orders Placed capacity being 1 in normal times and 2 in busy times; Order prepared capacity being dedicatedly 1 all the time; Order cooked capacity is traditionally 6 and

Order packed capacity being 1 in normal times and 2 in busy times, we have got the following key performance measure at 95% confidence level.

Table 8: Key Performance Metrics of Scenario 4

Key Performance Measure	Value
Average Order Completion Time	74.50 minutes
Average stockout time per month	621.54 minutes

Scenario 5:

5th scenario consists of Orders Placed capacity being dedicatedly 1 all the time; Order prepared capacity in normal times being 1 and in busy times 2; Order cooked capacity being traditionally 6 and Order packed capacity being 1 in normal times and 2 in busy times, we have got the following key performance measure at 95% confidence level.

Table 9: Key Performance Metrics of Scenario 5

Key Performance Measure	Value
Average Order Completion Time	74.23 minutes
Average stockout time per month	621.54 minutes

Scenario 6:

6th scenario consists of all the servers except Order cooked capacities being 1 in normal time and 2 in busy time and Order cooked capacity is kept traditionally 6, we have got the following key performance measure at 95% confidence level.

Table 10: Key Performance Metrics of Scenario 6

Key Performance Measure	Value
Average Order Completion Time	51.29 minutes
Average stockout time per month	621.54 minutes

Scenario 7:

7th scenario consists of Orders Placed capacity being 1 in normal times and 2 in busy times; Order prepared and Order Packed capacity being dedicatedly 1 all the time; Order cooked capacity is traditionally 6, we have got the following key performance measure at 95% confidence level.

Table 11: Key Performance Metrics of Scenario 7

Key Performance Measure	Value
Average Order Completion Time	80.1 minutes
Average stockout time per month	621.54 minutes

Scenario 8:

8th scenario consists of Order Placed and Order Prepared capacities being dedicatedly 1 all the time while Order Packed capacity being 1 in normal times and 2 in busy times and Order cooked capacity is 5, we have got the following key performance measure at 95% confidence level.

Table 12: Key Performance Metrics of Scenario 8

Key Performance Measure	Value
Average Order Completion Time	206.19 minutes
Average stockout time per month	621.54 minutes

Figure 30 shows the scenarios where the disruption probability is 1%.

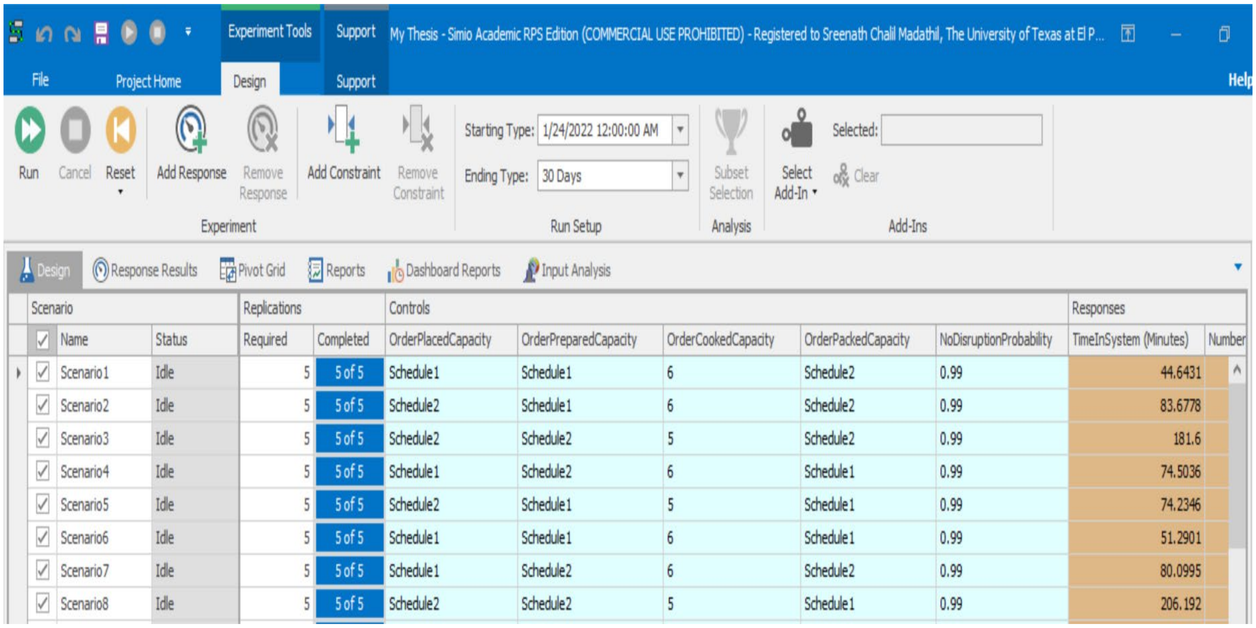


Figure 30: Scenarios of Experimentation in Disruption Probability 1%

4.3.2 DISRUPTION PROBABILITY 100%

Scenario 9:

1st scenario is as per the normal resources of the current system. Orders Placed capacity in normal time is 1 and in busy times 2; Order prepared capacity is remaining the same also; Order cooked capacity is traditionally 6 and Order packed capacity is keeping 1 all the time, we have got the following key performance measure at 95% confidence level.

Table 13: Key Performance Metrics of Scenario 9

Key Performance Measure	Value
Average Order Completion Time	16279.1 minutes
Average stockout time per month	621.54 minutes

Scenario 10:

2nd scenario consists of Orders Placed capacity being dedicatedly 1 all the time; Order prepared capacity in normal times being 1 and in busy times 2; Order cooked capacity being traditionally 6 and Order packed capacity keeping 1 all the time, we have got the following key performance measure at 95% confidence level.

Table 14: Key Performance Metrics of Scenario 10

Key Performance Measure	**Value**
Average Order Completion Time	14814.7 minutes
Average stockout time per month	621.54 minutes

Scenario 11:

3rd scenario consists of all the servers except Order cooked capacities being dedicatedly 1 all the time and Order cooked capacity is 5, we have got the following key performance measure at 95% confidence level.

Table 15: Key Performance Metrics of Scenario 11

Key Performance Measure	**Value**
Average Order Completion Time	16886.1 minutes
Average stockout time per month	621.54 minutes

Scenario 12:

4th scenario consists of Orders Placed capacity being 1 in normal times and 2 in busy times; Order prepared capacity being dedicatedly 1 all the time; Order cooked capacity is traditionally 6 and Order packed capacity being 1 in normal times and 2 in busy times, we have got the following key performance measure at 95% confidence level.

Table 16: Key Performance Metrics of Scenario 12

Key Performance Measure	**Value**
Average Order Completion Time	16891.8 minutes
Average stockout time per month	621.54 minutes

Scenario 13:

5th scenario consists of Orders Placed capacity being dedicatedly 1 all the time; Order prepared capacity in normal times being 1 and in busy times 2; Order cooked capacity being traditionally 6 and Order packed capacity being 1 in normal times and 2 in busy times, we have got the following key performance measure at 95% confidence level.

Table 17: Key Performance Metrics of Scenario 13

Key Performance Measure	Value
Average Order Completion Time	16351.8 minutes
Average stockout time per month	621.54 minutes

Scenario 14:

6th scenario consists of all the servers except Order cooked capacities being 1 in normal time and 2 in busy time and Order cooked capacity is kept traditionally 6, we have got the following key performance measure at 95% confidence level.

Table 18: Key Performance Metrics of Scenario 14

Key Performance Measure	Value
Average Order Completion Time	15915.4 minutes
Average stockout time per month	621.54 minutes

Scenario 15:

7th scenario consists of Orders Placed capacity being 1 in normal times and 2 in busy times; Order prepared and Order Packed capacity being dedicatedly 1 all the time; Order cooked capacity is traditionally 6, we have got the following key performance measure at 95% confidence level.

Table 19: Key Performance Metrics of Scenario 15

Key Performance Measure	Value
Average Order Completion Time	16810.1 minutes

Average stockout time per month	621.54 minutes

Scenario 16:

8th scenario consists of Order Placed and Order Prepared capacities being dedicatedly 1 all the time while Order Packed capacity being 1 in normal times and 2 in busy times and Order cooked capacity is 5, we have got the following key performance measure at 95% confidence level.

Table 20: Key Performance Metrics of Scenario 16

Key Performance Measure	Value
Average Order Completion Time	16852.1 minutes
Average stockout time per month	621.54 minutes

Figure 31 shows the scenarios where the disruption probability is 100%.

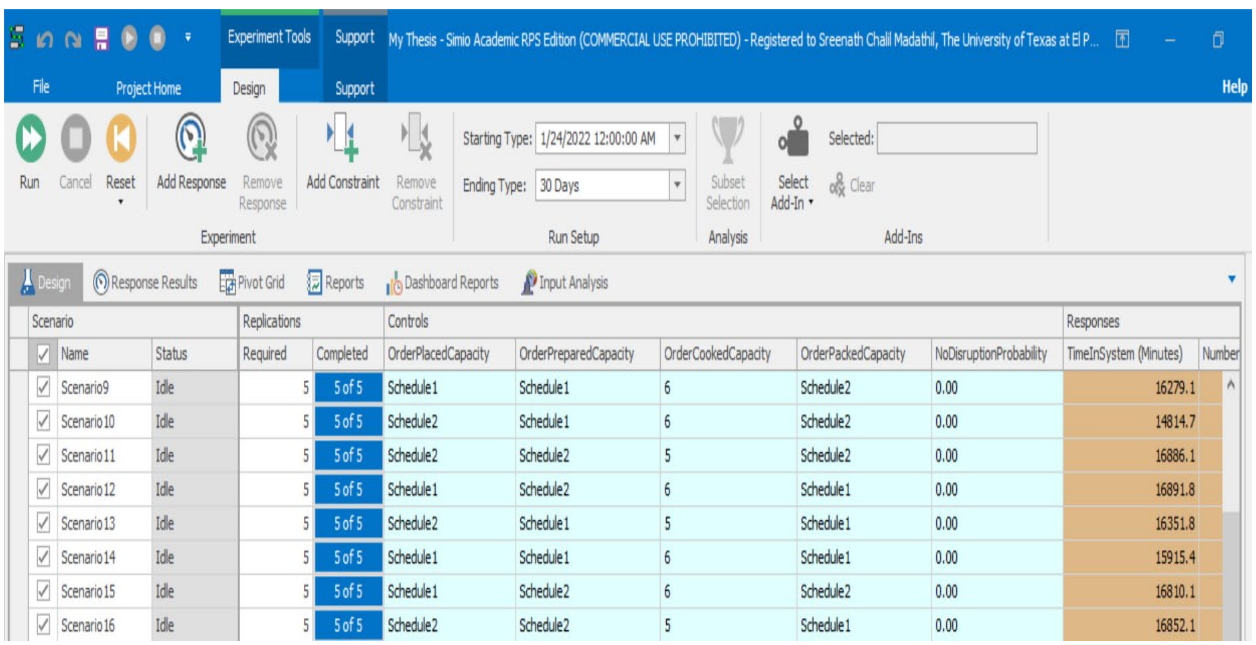


Figure 31: Scenarios of Experimentation in Disruption Probability 100%

4.3.3 DISRUPTION PROBABILITY 10%

Scenario 17:

1st scenario is as per the normal resources of the current system. Orders Placed capacity in normal time is 1 and in busy times 2; Order prepared capacity is remaining the same also; Order cooked capacity is traditionally 6 and Order packed capacity is keeping 1 all the time, we have got the following key performance measure at 95% confidence level.

Table 21: Key Performance Metrics of Scenario 17

Key Performance Measure	Value
Average Order Completion Time	582.20 minutes
Average stockout time per month	621.54 minutes

Scenario 18:

2nd scenario consists of Orders Placed capacity being dedicatedly 1 all the time; Order prepared capacity in normal times being 1 and in busy times 2; Order cooked capacity being traditionally 6 and Order packed capacity keeping 1 all the time, we have got the following key performance measure at 95% confidence level.

Table 22: Key Performance Metrics of Scenario 18

Key Performance Measure	Value
Average Order Completion Time	367.22 minutes
Average stockout time per month	621.54 minutes

Scenario 19:

3rd scenario consists of all the servers except Order cooked capacities being dedicatedly 1 all the time and Order cooked capacity is 5, we have got the following key performance measure at 95% confidence level.

Table 23: Key Performance Metrics of Scenario 19

Key Performance Measure	Value
Average Order Completion Time	5212 minutes
Average stockout time per month	621.54 minutes

Scenario 20:

4th scenario consists of Orders Placed capacity being 1 in normal times and 2 in busy times; Order prepared capacity being dedicatedly 1 all the time; Order cooked capacity is traditionally 6 and Order packed capacity being 1 in normal times and 2 in busy times, we have got the following key performance measure at 95% confidence level.

Table 24: Key Performance Metrics of Scenario 20

Key Performance Measure	Value
Average Order Completion Time	4336.25 minutes
Average stockout time per month	621.54 minutes

Scenario 21:

5th scenario consists of Orders Placed capacity being dedicatedly 1 all the time; Order prepared capacity in normal times being 1 and in busy times 2; Order cooked capacity being traditionally 6 and Order packed capacity being 1 in normal times and 2 in busy times, we have got the following key performance measure at 95% confidence level.

Table 25: Key Performance Metrics of Scenario 21

Key Performance Measure	Value
Average Order Completion Time	967.87 minutes
Average stockout time per month	621.54 minutes

Scenario 22:

6th scenario consists of all the servers except Order cooked capacities being 1 in normal time and 2 in busy time and Order cooked capacity is kept traditionally 6, we have got the following key performance measure at 95% confidence level.

Table 26: Key Performance Metrics of Scenario 22

Key Performance Measure	Value
Average Order Completion Time	1011.39 minutes
Average stockout time per month	621.54 minutes

Scenario 23:

7th scenario consists of Orders Placed capacity being 1 in normal times and 2 in busy times; Order prepared and Order Packed capacity being dedicatedly 1 all the time; Order cooked capacity is traditionally 6, we have got the following key performance measure at 95% confidence level.

Table 27: Key Performance Metrics of Scenario 23

Key Performance Measure	Value
Average Order Completion Time	1685.95 minutes
Average stockout time per month	621.54 minutes

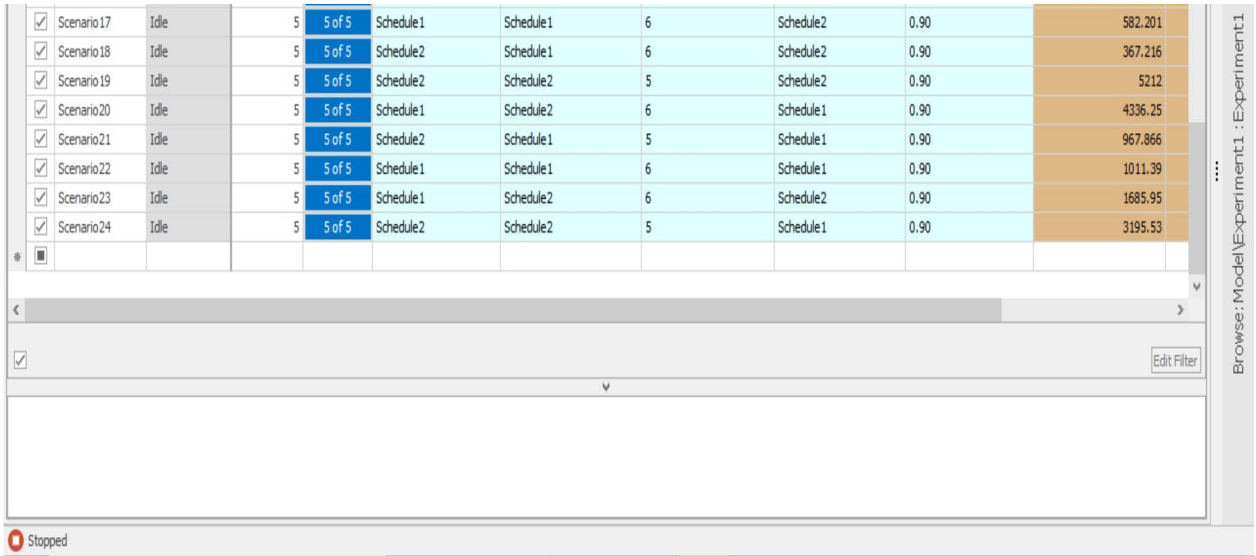
Scenario 24:

8th scenario consists of Order Placed and Order Prepared capacities being dedicatedly 1 all the time while Order Packed capacity being 1 in normal times and 2 in busy times and Order cooked capacity is 5, we have got the following key performance measure at 95% confidence level.

Table 28: Key Performance Metrics of Scenario 24

Key Performance Measure	Value
Average Order Completion Time	3195.53 minutes
Average stockout time per month	621.54 minutes

Figure 32 shows the scenarios where the disruption probability is 10%.



Scenario17	Idle	5	5 of 5	Schedule1	Schedule1	6	Schedule2	0.90	582.201
Scenario18	Idle	5	5 of 5	Schedule2	Schedule1	6	Schedule2	0.90	367.216
Scenario19	Idle	5	5 of 5	Schedule2	Schedule2	5	Schedule2	0.90	5212
Scenario20	Idle	5	5 of 5	Schedule1	Schedule2	6	Schedule1	0.90	4336.25
Scenario21	Idle	5	5 of 5	Schedule2	Schedule1	5	Schedule1	0.90	967.866
Scenario22	Idle	5	5 of 5	Schedule1	Schedule1	6	Schedule1	0.90	1011.39
Scenario23	Idle	5	5 of 5	Schedule1	Schedule2	6	Schedule2	0.90	1685.95
Scenario24	Idle	5	5 of 5	Schedule2	Schedule2	5	Schedule1	0.90	3195.53

Figure 32: Scenarios of Experimentation in Disruption Probability 10%

Figure 33 shows the visual representation of the different scenarios.

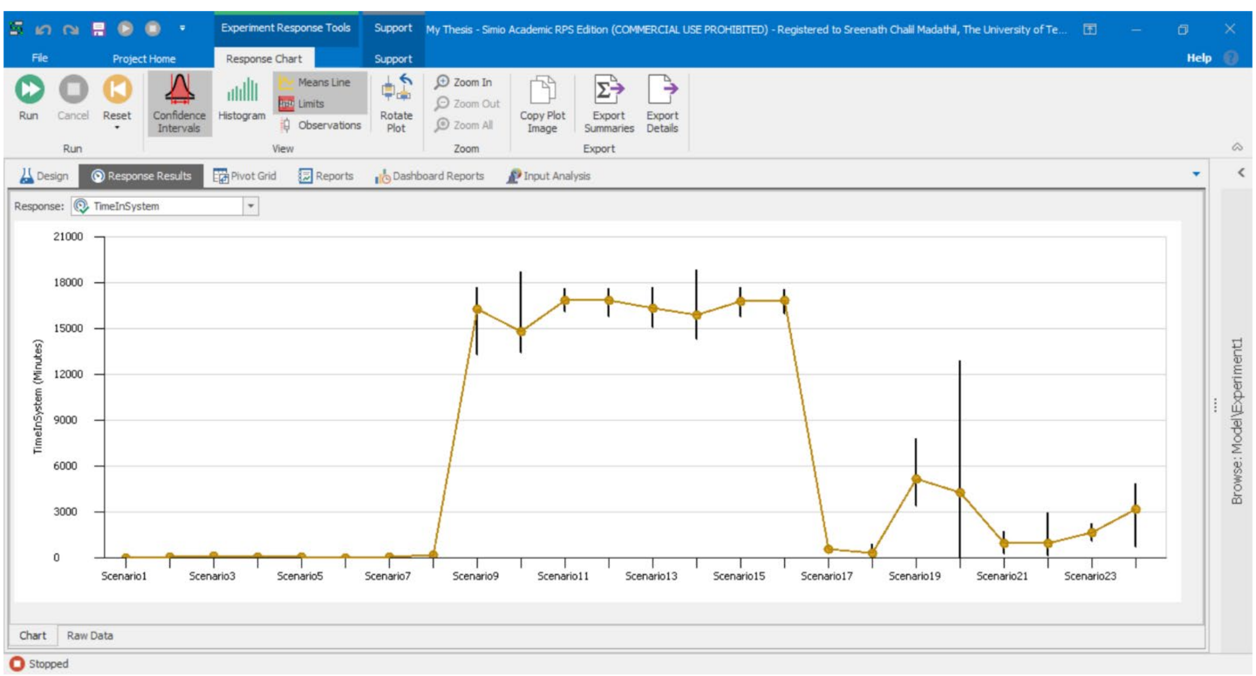


Figure 33: Visualization of Different Scenarios in Experimentation Based for Different Disruption Probabilities

4.4 RECOMMENDATION

Different Scenarios were tested with the same processing times of each station and same order arrival rate but for different disruption probability. Therefore, current combination in 1% disruption probability is the best combination as service time is 44.64 minutes. So, Order Placed and Order Prepared server should have 1 employee in the normal time and 2 employees in the busy shift that is 4 pm to 10 pm and Order cooked should have 6 employees as usual and Oder Prepared server is fine with just 1 employee all the time. In this way, the service time or the order completion time will be the least. Any cut off employees will increase the service time.

5. CONCLUSIONS, LIMITATIONS, AND FUTURE WORKS

In our research, we created a simulation model that replicates the operations of a small restaurant's supply chain in order to investigate alternatives that will improve their service and delivery times. the most important performance metrics were examined in order to identify the best implementations that will improve the restaurant's service and enable them to become a resilient supply chain capable of overcoming any situation, such as the COVID-19 pandemic. We have recommended the optimal resource allocation in each server based on the least service time and utilization of each server. We have also analyzed the time loss for stockout, inventory replenishment and finally the what-if scenarios when one or more potential suppliers are out. the model can be used as a Decision-Making System, allowing the customer to generate new ideas and make innovative decisions by comparing scenarios.

5.1 LIMITATIONS

There are certain limitations in the modeling approach. the main limitation is the model has shortage in small details that a restaurant can face in reality. There are times when employees are absent from work, end up leaving shifts early, take long breaks during their shifts, or have a bad day in a fast-food restaurant. In employee scheduling, these things are not considered, which is considered the constant work schedule structures of the restaurants. the model is only limited to serving in restaurants and self-take out. As delivering to the customers is not adding any value to the key performance parameters of the model, we have just mentioned the process of delivery, not doing any processing for it in the model. Sometimes some ingredients from the supplier are rotten which is seen in times of order processing which can make a significant delay in service time. Moreover, due to long line, some customers feel disturbed and left immediately. This bulking effect also is not considered for modeling. Another limitation is that the model doesn’t include expenses and an analysis of costs in big picture, just to have a cost optimization model. Hiring a new employee can cost more than the expense of an existing employee which also haven't been picturized in the experimentation.

5.2 FUTURE WORKS

There are some future works that can be done to make the research more accurate. Overall process of the cost can be incorporated in the model using the opt quest which can give an idea of specific expenses for the employees and cost-cutting scenarios. Bulking options can be added to see how many customers are leaving immediately due to late delivery or long queue. In the optimization model, we need to put the data of the boundary values and calculate the minimum cost in the disruption period. Also, there can be research where multiple top-level suppliers are disrupted and there is a requirement for more than one safety supplier. Moreover, some scenarios can be added if the shortage from the safety suppliers happens or if they are out due to unavoidable reasons in the agreement period, what will be the backup or compensation. In the case of delivering to the customers outside, how late or variations can happen or what if scenarios like if wrong addresses are given, the order is not picked at the right time, the order needs to be remade these things can be an interesting future extension of the modeling process.

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