Simulation-Based Modeling of an End-To-End Supply Chain System

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Abstract - Supply chains (SC) are crucial in modern society, with numerous companies competing globally. However, their complexity and systemic nature pose significant challenges in managing ETE-SC. Decision makers seek modeling tools to understand, control, develop, or evaluate their ETE-SC in the face of insecurity, hazards, and volatile markets. This study aims to define a general simulation modeling approach for any ETE-SC to assist academics and decision-makers. The research highlights the need for modeling an ETE-SC and addresses the difficulties and problems related to simulating complicated systems. The systematic literature review approach yields a dual theoretical contribution, evaluating various contributions to knowledge surrounding simulation approaches and proposing a conceptual framework for modeling such systems using simulation.

Keywords: Supply Chain (SC), Supply Chain Network, End to End (ETE), Supply Chain Network (SCN)

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I. INTRODUCTION

Supply chains (SCs) play a significant role in the modern world. Numerous enterprises operate in the global market, where individual businesses are now seen as essential components of an end-to-end supply chain (ETE-SC) system rather than as distinct legal entities. Their extensive, complicated, and systemic nature is rightfully acknowledged as one of the main obstacles and issues in administering ETE-Supply Chain[1]. Decision makers are looking for modelling tools to be able to comprehend, control, develop, or evaluate their ETE-Supply Chain in the age of uncertainty, hazards, and market volatility. The purpose of this study is to define a general simulation modeling approach that can be applied to any ETE-Supply Chain in order to assist academics and decision-makers. The study employs a simulation technique and creates a general manual for building ETE-Supply Chain simulation models. It is a thoughtful investigation into the effects of the building of a simulation model when there are generic components from the suggested conceptual framework present. Industry experts validate the conceptual framework, and illuminating observations are made. Systems & networks for the supply chain (SC) have been essential components of the modern world[2].

Table 1: Nomenclature

NOTATION	DISCRIPTION
SC	Supply Chain
SCM	Supply chain management
SCM:IJ	Supply Chain Management: An International
SCOR	Supply Chain Operations Reference
SCN	Supply chain network
SLR	Systematic literature review
SM	Scientific management
SMPT	Simulation Modelling Practice and Theory
SO	Systemic organizational
ETE	End to End
C	Computational complexity
MD	Master Data
R	Retailers
RL	Reinforced Learning
RM	Raw materials
RQ	Research question
RSM	Response Surface Methodology
S	Supplier
SKU	Stock keeping unit

II. METHODOLOGY OF MODEL

The study's goal and background were defined, while a number of issues regarding the best way to simulate an End-to-End Supply Chain (ETE-SC) were brought up for further thought. In works on simulating supply chain (SC) systems, a literature review strategy examined the significance of diversity that systemic philosophy and resulted in the creation of a framework of concepts. In order to preserve the integrity of the study, this chapter explains the investigation's design, identifies the contribution of the chapter's organization to the general framework, and emphasizes the significance of each research question. This chapter will devote a significant amount of space to the research paradigm[3].

Ontology, epistemology, and methodology are the three components that make up the research paradigm; consequently, by looking at the research philosophy, the researcher determines the methodological approach, which influences how knowledge is created and clarifies the research. The section is going to commence by looking at the philosophical foundations of the work that has been done, which serves as an important first step in determining the character of the interaction between the two disciplines - theory and practice. The study devotes a lot of time to discussing the methodology used in this study and elaborates on each of the elements shown in Table 3.1. The present section connects every aspect of the research method in the larger setting for simulating End to End supply chain networks, which follows discussions on the components of study layout, the function of modeling, and defining the field of investigation. The necessity towards a general strategy for simulating End to End supply chain (ETE-SC) networks employing modeling which may take into account each of the three elements established in the theoretical foundation is going to be explained, followed by discussions of applications of operation research (OR) methods and combined/hybrid modeling approaches.

III. DESIGNING AN EXPLANATION FOR THE ETE-SUPPLY CHAIN SIMULATION MODEL

To investigate complex systems like the ETE-Supply Chain, modeling technique, commonly known as computer simulation, has often been utilized. When examined independently, every single one of the components shown in Figure could appear easy to understand and are logically backed up by earlier studies. yet another perspective is considered from the standpoint of the ETE-Supply Chain system, the results of relationships among its components might not be immediately obvious, simulation may be utilized for a range of academic applications and enables for the examination of the system's operation under concurrent activities.

• For the purpose of to forecast system behavior. This can be done by examining the results of simulation runs or by conducting an empirical investigation to evaluate a concept. This makes it possible to see how model variables respond to changes in the data or the model's structural elements.

• To show that the modeled processes and policies may exhibit specific system behaviors under predetermined conditions (in the current research, these conditions would be structural and organizational when taking into account predetermined computational elements).

• To identify/unveil unanticipated system behaviors resulting from interplay between its constituent parts. By executing several situations, simulation may be utilized in exploratory research to assess these behaviors.

All of the components of the ETE-Supply Chain network had been collected for this research utilizing SLR, and the effects of modeling them have been explored through modeling. Using training for explanatory purposes may also be utilized to show that a model is feasible. As a result, the current study demonstrates how modeling can be impacted by using components from the conceptual framework in the ETE-SUPPLY CHAIN simulation model. The process of research is shown in Figure from the establishment of the study purpose as well as goals via a thorough evaluation of the literature and the creation of the ETE-Supply Chain paradigm to study verification and verification of the model. The context for this research was given within the introduction chapter. It emphasized the necessity of the general ETE-Supply Chain system model, which was developed via preliminary examination of the available literature, participation in training sessions and meetings, and numerous conversations with professors and business professionals.

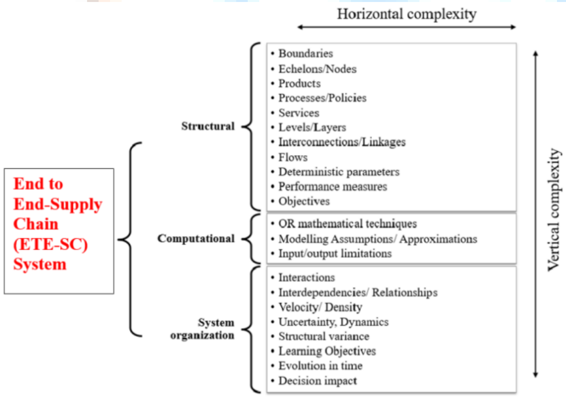

Figure 1: Simulation-based general framework for modeling the ETE-Supply Chain network

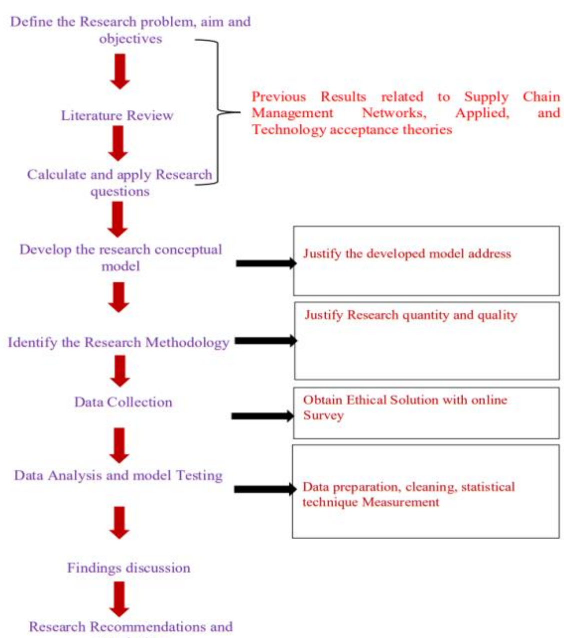

Figure 2: Modeling of Research process.

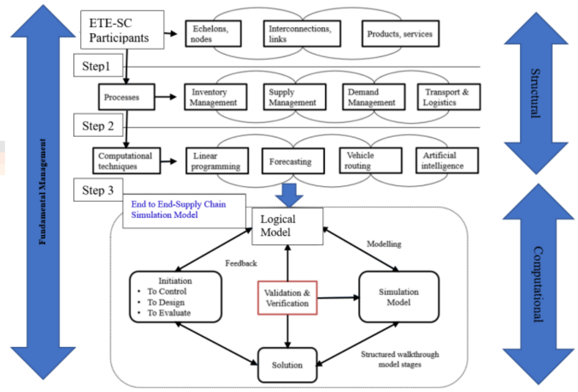

Figure 3: The theoretical structure includes a general ETE-Supply Chain modeling system.

A. Basic Model Components

The goal of this study attempts to progress information by creating a theoretical integrated computational modeling that utilizes the elements that best represent the operation of an ETE-supply chain system (epistemology) in order to comprehend it. On the other hand, it respects a general systems characterization of sciences. The 'scientific enquiry paradigm by Mitroff, [33] which offered a comprehensive viewpoint and method for solving issues inquiry, constitutes an important framework that has been accepted within this research, as was covered in the preceding sections. The modified version of the Mitroff et al. [33] model was intended to improve the research's design while incorporating scientific management practices[4].

B. Structure Foundation

This foundational element takes into account several ETE-Supply Chain structural elements including the number of echelon & nodes, Supply Chain levels, various processes inside the Supply Chain, participation and procedure features, etc. These may negatively affect the modeling of ETE-Supply Chain& their general complexity. Along alongside the kind, quantity, & arrangement of procedures, the amount of goods and services supplied could add to complex. It is important to consider all elements before creating a model that is scientific in nature. However, only a few tiers could be given consideration depending on the project's objectives. As a consequence, the list of generic elements in the model remains unchanged, but certain of their characteristics (attributes) might be specific to a given ETE-Supply Chain technology being investigation as shown in table. The corresponding correctness regarding the ETE Supply Chain system's boundaries and echelons, the volume of products or services under scrutiny, or the connections among Supply Chain users are just a few of the critical components which must be protected. The framework's objectives, predictable variables, as well as crucial performance metrics should all be approached using the same caution.

Table 2: Features of structural components

Products	❖ Single or multiple
Service	❖ Service type provided
The procedures/policies	❖ Transportation (delays) ❖ Production Planning ❖ Demand / Supply Planning ❖ Inventory Management
Tiers, nodes, borders, layers, and levels	❖ Defined
Performance measures	❖ Defined
Interconnections	❖ Defined
Flows	❖ Items ❖ Knowledge ❖ Cash
Parameters	❖ Defined
Objectives	❖ Defined

C. Technological Pillar

Regarding the computational pillar, this study makes the case that modeling the ETE-Supply Chain should take computational elements into account in relation to the methodologies and techniques used by enterprises to assist decision-making. Due to the wide variety of operations research/management science (OR/MS) methodologies, including artificial intelligence, forecasting, vehicle routing algorithms, and linear programming, this is especially important for creating a generic ETE-Supply Chain system model. As a result, this need must be included in the model and taken into consideration while developing the framework for simulation. Regarding the computational pillar, this study makes the case that while modeling the ETE-Supply Chain, computational factors should be taken into account in relation to the strategies/mechanisms employed by enterprises to assist in decision-making. This is especially important when creating a general ETE-Supply Chain system model since so many operations research/managements science (OR/MS) approaches, such linear programming, forecasting, truck routing systems, or artificial intelligence, are employed by enterprises. As a result, this must be taken into consideration while developing the simulation model and represented in the model.

Typically, the modeler must select parameters pertaining to the processes being modeled, the number of goods being produced, the number of echelons, the number of important actors, etc. The ability utilization rate or the arrival time of goods are two examples for input characteristics. The results of the simulation run may also change, especially if stochastic variables are utilized, as they frequently represent various behaviors in complex systems. To access the typical system behavior and provide a relevant explanation of the ETE-Supply Chain system model's performance in the context of its intended use, numerous rounds are necessary in this case[5].

D. Systemic Transformation in Organizations

The paradigmatic perspective of the system is referred to as the systemic operational pillar, which reflects the multifaceted degree of interactions and connections among the components that make up the system as shown in table. This happens as a result of metaphysical views, that regard ETE-Supply Chain as both an actual thing and a perfect being. At this stage, much thought must be given to the modeling goal & systems under discussion. This is essential to make certain that the framework takes into account the connections and dependence that exist among important nodes in a procedure, levels, and players.

Table 3: Features of systemic organizational pillars

Interactions, connections, and interdependence • Links in the system that the user defines are present
Learning • Evaluation of system, user defined

Impact on decisions, uncertainties, and dynamics • Defined
Changing through time • Defined

IV. DEVELOPMENT OF AN END-TO-END SUPPLY CHAIN SYTEM MODEL

The goal of the following section intends to give an exhaustive description of the creation for using ETE-Supply Chain system modeling framework. The investigation used a combined approach built on modeling, training, & SCM concepts to highlight the significance alongside difficulties associated with modeling ETE-Supply Chain networks.

A comprehensive guide for creating models for simulation is provided as well, along with the repercussions and impacts that particular concepts form the theoretical structure might possess on the procedure of creating models used in simulation.

ARENA SIMULATION MODELLING ENVIRONMENT

Arena simulation software was used in this study due to its ability to simulate intricate supply chain systems. The software was chosen due to its ability to apply metamodel modeling techniques to multi-echelon supply chain situations, allowing statistical investigation of input-output variables. Arena's documentation, under Help>Arena Product Manuals>Template Developer's Guide, provides more information on simulation modeling in Arena, specifically theme creation. While Arena modeling and simulation systems have been extensively covered in various courses, there is a lack of literature on how simulation methods can be used to model complex ETE-Supply Chain systems. To address this, it is recommended to focus on the theoretical foundations of the system and how to apply this knowledge, necessitating further research into complex ETE-Supply Chain modeling methodologies.

According to this study's findings, combining modeling approaches provides a way for dealing with all facets of complicated ETE-Supply Chain frameworks.

In order to achieve this, the current panels of modules have been frequently used to create Supply Chain-related designs, which Arena is able to configured to accommodate the following features:

• Imported MS Office files, allowing the program to exchange data with Excel spreadsheets & Access databases.

• Visual Basic for Applications (VBA)-based automation

• Creation of fresh modules via Framework Programming in the Commercial Version of Arena

These software features offer the potential for expanding the fundamental models and creating more reliable hybrid models, allowing for the integration as follows:

(a) Definition of Arena Simulation

Entity: Refers to a separate item that exists. In SCs, this could be a consumer, a good or item, a piece of paper, an ingredient or component which follows a procedure, or another activity including waiting in a line and waiting.

• A module represents a construction with variables whose basic logic directs an entity via it whenever a copy of the module appears in the model view.

Models can be developed using modules, which are chosen using the template interface.

• Module definition: All details about a specific module, including its layout, the data it uses, including any movement, remain in the template panel library file.

• Adding a module to the modeling window is known as a module example.

• Logic window: This represents the modeling logic connected to each occurrence of an element in the model windows as well as the information that it produces. Model logic comprises the modeling logic connected to the Arena architecture.

• The term operand may be used in two distinct situations:

a. when building simulation models, it means to every section instance's conversation container, that includes a number of areas with flexible numbers.

b. when designing templates, during which the operands that have been established or generated by putting a component in the conversation development opening.

(b) Organizing Principles

Arena's organizational framework allows users to create complex simulation models by using template panels and evaluation modules. This approach allows for a top-down model to be developed by developing sub-models, reducing system changes and improving model reliability. Integrating modules to describe supplier operations can create a model that can stand alone or be used as a sub-model in an extended supply chain. The modeling program's organizational characteristics show that modules have been established using other modules, which can be leveraged to create new, higher-level components. The specification of frequently used concepts, company-specified processes, and templates is located at the top of the modeling hierarchy and must be created by a modeler. Application solution templates, a collection of pre-defined sections, form the foundation of the modeling structure. For example, algorithms can be used to replicate wrapping activities in a model, compared to the containers design panel for machines or conveys.

V. MODEL DESIGN INITIATION AND CONCEPT DEVELOPMENT

A. Issue Description

This section's description of the issue makes reference to both the ETE-Supply Chain technology and the simulation model. A model for simulation has been developed to accommodate the demands of an administrator that can be utilized as a means to design, control, or assess the SC.

The problem statement, if one is available, ought to be determined by an actual issue. If not, the main metrics can be utilized to identify areas for development. The model should accurately replicate a real SC system. The sophisticated ETE-Supply Chain and simulation frameworks are the main focus here, but it's important to understand the seriousness and complexity of the issue because there are a number of simulation-alternative strategies that are able to be used.

B. Developing the Research's Concept

A crucial stage in any simulation research project involves the conceptual modeling. This step's major goal consists of providing a system definition, identify the goals, inputs, and outputs, and then describe the subject matter of a non-software-specific model including the fundamental presumptions that drove the model's construction. The layout of a conceptual model can be influenced by a variety of factors, but when duplicating a real system, the amount of abstraction—or, to put it another way, the level of simplification—is frequently viewed as crucial. The work of this research is added to the specification within the shape of important components that define the structure and organization of an ETE-Supply Chain, whether one exists or not.

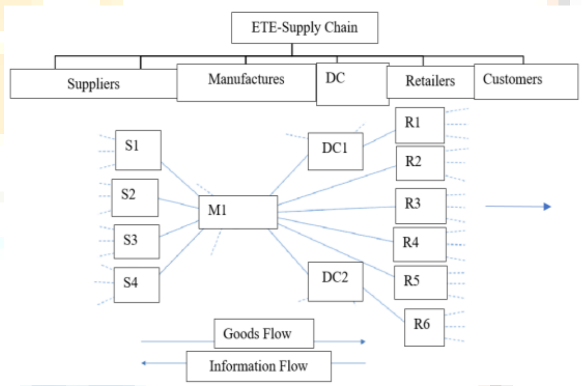

Figure 4: Supply Chain network structure.

C. The Creation of Simulation Models

The following section covers the models, sub-models, including components that were employed along with specifics regarding the Arena simulation model creation procedure. The complexity of these networks as well as the modeling implications frequently requiring the synthesis of knowledge from various disciplines, such as computer engineering, OM, or OR/MS, are also to blame for the difficulties and problems associated with developing an End to End –

Supply Chain modeling approach. The aforementioned challenges and challenges are additionally assigned towards a lack of visibility as well as comprehension of the structure and organization of the entire end-to-end Supply Chain structure.

Therefore, structural elements of the Arena training setting have been taken into consideration therefore an array of pertinent models have been constructed in order to portray all pertinent components of an ETE-Supply Chain.

The general ETE-Supply Chain computational model logic including a description of the multilevel model framework are the main topics of this chapter. Accordingly, a modular design has been created established and sub-models have been developed in Arena where different sub-models are capable of being utilized & are able to stand alone as a separate from one another, independent design according to the demands of the modelers and/or company needs.

D. End-To-End – Supply Chain Simulation Design

The simulation framework created for the present research was put into effect in MS Excel 2016 using Arena software version 14.7. The E2E-SC system's logistical operations were modeled using Arena in terms of information and product flow. To simulate an FMCG supply chain the network, numerous models and sub-models were created. Arena models for simulation and MS Excel were combined in the current research's integrative technique, which can be also known as a combination of methods as shown in figure.

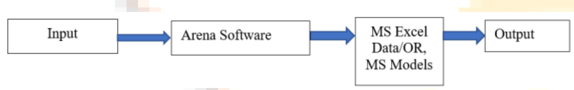

Figure 5: Relationship between MS Excel Master data as well as OR/MS models in Arena.

E. End to End – Supply Chain model validation and verification

Table 4: The validity as well as dependability of the ETE-Supply Chain simulation framework.

Group	Summary
Interview subjects	Interviews with the SC director and SC capability managers; purposeful sampling. Various functional domains and industry backgrounds.
Explanation of the simulation framework principles	A theoretical framework that helped with the creation of models. Foundation along with empirical validation of models with business and academic specialists.
Internal verification of the modeling procedure	confirmation using organized inspections to confirm that a source code's correct information is there. The simulation model's logic and design, together with the algorithms employed, were analyzed. Continuity of the model has been verified. The creation of the model became documented extensively.
Application of simulation models in Business	Clear definitions of the study's context and participants are necessary for generalization.
Evaluation of model outcomes	Interviews have been employed to support the creation of simulation frameworks. To facilitate verification of models, a moving model was created. To verify the correctness of the model, performances records have been reviewed.

Due to concerns over privacy, interviews did not take place, but detailed notes have been taken then physically recorded in the MS Excel file as shown in table. The following steps are taken as shown in figure.

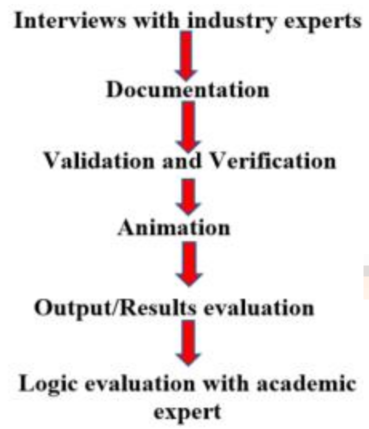

Figure 6: Validation and verification components of the E2E-SC model

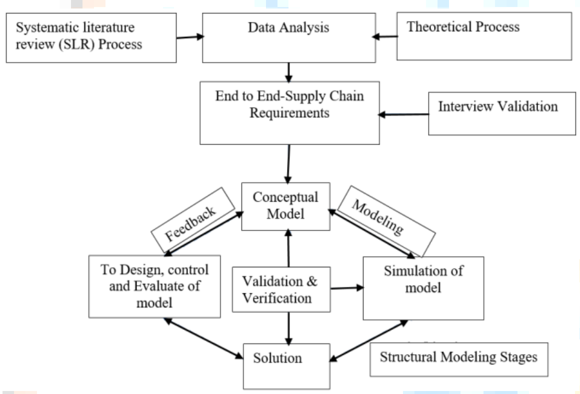

Figure 7: The conclusion, methodology, and validation of data.

VI. CONCLUSION

The research's goals and objectives were defined in part by the research questions. Recall that the goal of the research project was to specify requirements for modeling an end-to-end supply chain (ETE-Supply Chain) system when using simulation technique as well as to design a generic end-to-end supply chain system model using simulation. The following set of goals were suggested to accomplish this:

• To create a conceptual modeling framework for an ETE-Supply Chain system that considers complexity theory and system thinking.

• To create a digital model through simulation that offers the building blocks for merging different modeling approaches.

• To assess the modeling implications when various components of the suggested conceptual framework are incorporated into the computerized/scientific model.

• To verify the computerized/scientific model and conceptual research framework.

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