Czech University of Life Sciences Prague

Faculty of Economics and Management
Department of System Engineering and Informatics
Diploma Thesis

Designing an Optimized Logistic Network: In The Case of Fuel And Lubricant Distribution

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DIPLOMA THESIS ASSIGNMENT

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Systems Engineering and Informatics
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Thesis title

Designing an optimized logistic network: in the case of fuel and lubricant distribution

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Objectives of thesis

The main objective of this thesis is design optimized distribution logistics network model, minimizing overall cost in transportation and other operational cost.

- To analyze the current company practices regarding their logistics network and identify main levers for cost reduction.

- Forecast logistics demand using deep learning algorithms.

- To merge movement of product by grouping shipment.

- To optimize total travel time and total costs of delivery of commodities.

Methodology

Methodology of this diploma thesis is based on study and raw data analysis. The practical part focuses on designing optimized distribution logistics network using Mixed Integer Linear Programming with the help of excel.

- Literature review
- Data Collection and Dataset Preparation
- Data Processing Phase
- Results and analysis
- conclusions and suggestions

The proposed extent of the thesis

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Keywords

Mixed Integer Linear Programming (MILP), cost optimization, Logistic network design, Transportation, inventory, warehouse, Supply chain, distribution centers

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Declaration

I declare that I have worked on my master's thesis titled " Designing an Optimized Logistic Network: In The Case of Fuel and Lubricant Distribution" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the master's thesis, I declare that the thesis does not break any copyrights.

In Prague on 2022
Hamame Berhanu Woldegiorgis

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Designing An Optimized Logistic Network: In The Case Of Fuel And Lubricant Distribution

Abstract

This thesis presents a general model in mixed integers linear programming that integrates the proposed design to develop optimization for solving distribution logistics networks. The study targeted logistic service as truck distribution in the area of Gulf coast Texas, Trucks are used by fuel and lubricant distribution firms to serve their consumers. The challenge is to create a set of routes that minimizes the amount of kilometers traveled and vehicles used, while meeting client demand and reducing transportation cost at the same time. Two warehouses as a local distributor, ten customers and one refinery has been included. Kilometer's traveled by vehicles is decrease by 18.4%, and 30% of transportation cost has decrease as well. Freight forward is one of the big issues in logistics services, in this study cost of freight forwarders has been forecasted. Forecasting allows a logistics service provider to reduce operational and management costs while maintaining a high level of service. NN is chosen as a time series forecasting method because of its feasibility. The design model reports an efficient solution which provides sufficient information for the administration.

Keywords: Mixed Integer Linear Programming (MILP), cost optimization, Logistics network design, Transportation, inventory, warehouse, Supply chain, and distribution centers

Navrhování optimalizované logistické sítě: V případě distribuce paliva a maziv

Abstrakt

Tato práce představuje obecný model v lineárním programování smíšených celých čísel, který integruje navržený návrh pro vývoj optimalizace pro řešení distribučních logistických sítí. Studie se zaměřila na logistické služby, jako je distribuce kamionů v oblasti pobřeží Mexického zálivu v Texasu. Nákladní vozy používají firmy zabývající se distribucí paliv a maziv, aby sloužily svým zákazníkům. Úkolem je vytvořit soubor tras, který minimalizuje množství ujetých kilometrů a používaných vozidel a zároveň uspokojí poptávku klientů a zároveň sníží náklady na dopravu. Byly zahrnuty dva sklady jako lokální distributor, deset zákazníků a jedna rafinerie. Kilometr ujetý vozidly se snížil o 18,4 % a snížilo se také 30 % nákladů na dopravu. Přeprava nákladů je jedním z velkých problémů v logistických službách, v této studii byly předpovězeny náklady na přepravce. Prognózování umožňuje poskytovateli logistických služeb snížit provozní náklady a náklady na správu při zachování vysoké úrovně služeb. NN je zvolena jako metoda prognózování časových řad kvůli své proveditelnosti. Návrhový model hlásí efektivní řešení, které poskytuje dostatečné informace pro administraci.

Klíčová slova: Smíšené celočíselné lineární programování (MILP), optimalizace nákladů, návrh logistické sítě, doprava, zásoby, sklad, dodavatelský řetězec a distribuční centra

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LIST OF ABBREVIATIONS

F&L	Fuel and lubricants
COG	Cost of products sold
SKU,	Stock keeping unit
WH	Warehouse
DC	Distribution Center
RNN	Recurrent Neural Network
SCM	Suppy chain management
SWOT	Strength, Weaknesses, Opportunity, Threats
MILP	Mixed integer linear programming
TPL	Third-party logistic

1. Introduction

Supply chain management controls the forward and reverse movement, handling, and storage of products between origin and distribution points. The art and science of collecting, producing, and distributing material and merchandise in the correct location and amounts in an industrial context.

Logistics are part of supply chain management coordinates varied tasks required to urge the proper product to the proper customers at the proper time. More comprehensively, it also processes how resources are acquired, stored, and routed to their final destination within the established specifications and time frames at the lowest cost. The term is currently commonly used in the business sector.

The APICS Dictionary, 16th edition, describes the entire cost concept of logistics because the concept of all logistical decisions that provide equal service levels should favor the choice that minimizes the entire of all logistical costs and not be used on cost reductions in one area alone, like lower transportation charges. These days leading supply chain companies develop functional analysis and activity-based costing activities that measure the entire cost of logistics. Now the aim for logistics is to be cost-effective as determined by a benefit-cost analysis, taking under consideration how a logistical service failure would impact a customer's business. According to the 30th annual "State of Logistics Report" by the Council of Supply Chain Managements Professionals, United States companies spent US$1.64 trillion for logistical services in 2018. Most of the time the amount is nearly 669 billion USD for motor carrier transportation and 368 billion USD was spent for other forms of transportation, which is over 63% of the total logistic cost.

This thesis will design an optimized distribution logistics network model by minimizing overall cost in transportation and other operational costs. It also helps to make the best decision on the allocation of facilities with lower logistics costs. Will also consider demand, supply and industry capacity. To achieve the research objective, the study deals with a particular company known for manufacturing oil, gas and chemicals, based on analyzing secondary data as an example. The findings from this study can be applicable for other similar companies as well.

1.1 Company Description

Exxonmobil Corporation is the largest publicly traded international oil and gas company formed by John D. Rockefeller and his associates in 1870. ExxonMobil's headquarters is located in Irving, Texas. In 2021, ExxonMobil's revenue was $ 285.64 billion.

Mission of the supply chain of ExxonMobil is to deliver the right Materials, Right Time, Safely & Easily, at the Lowest Total System Cost" the company located 24 countries, 3GBCs, 71 warehouse operations, and 4.5G inventories. There are several departments; Upstream, downstream and chemicals. For oil & gas operations, logistics represent from 8 to 14% of the annual expenditures, it depends on the phases and nature of operations, and this might increase up to 30%.

The study data used is from one of the biggest refineries of ExxonMobil located in the Gulf Coast (PADD 3) called Baytown refinery.

Fuels and Lubricants (F&L) is a sub-company which focuses on distributing high-quality F&L, providing technical application expertise around the World. The lubricant brand names that ExxonMobil F&L distribute are Mobil 1, Mobil Delvac and Mobil SHC. They distribute products through direct sales and distributor channels. ExxonMobil is the global supplier of premium oils and lubricants to construction and mining equipment manufacturer Caterpillar Inc, Toyota Corporation, and the Lube Change Centers.

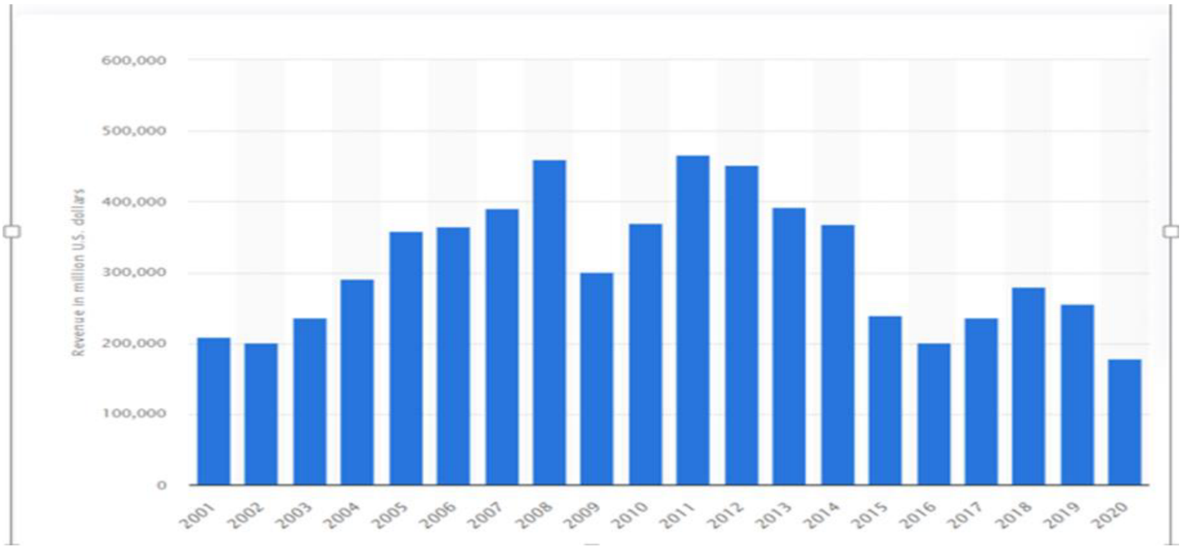

Figure 1Opreating revenu of exxonmobil 2001-2020

The method used in this research is to use the Mixed Integer Linear Programming (MILP). ILP is a method to create mathematical models to achieve research objectives. There is no primary data provided in this paper, all data comes from secondary data sources. There are raw statistics of lubricant supply and consumption made by the US Energy Information Administration's SEDS database.

2. Objectives and Methodology

The general and specific objectives of this research will be described in this section.

2.1 Objectives

The main objective of this thesis is design optimized distribution logistics network model, minimizing.

- To analyze the current company practices regarding their logistics network
- and identify main levers for cost reduction.
- Forecast logistics demand using deep learning algorithms.
- To merge movement of product by grouping shipment.
- To optimize total travel time and total costs of delivery of commodities

2.2 Methodology

To achieve the objectives of the study, the methodology to be used in this research follows three main steps, first receiving raw data then analyzing using excel spreadsheets and finally providing outputs of findings. The method used in this research is to use Integer Linear Programming.

2.3 Literature review

Literature review is referred to as a theoretical framework or research background. Reviewing relevant academic literature is relevant to our problem and the results of our literature review are used to inform the possible solutions to solve the logistics problem.
The network optimization literature establishes a high quality body of work and summarizes the lessons learned and the most applicable applications of this project.

2.4 Data Collection and Dataset Preparation

Secondary data has been used in this study, historical data of companies engaged in the production and distribution of gas, oil and chemicals. Secondary data include customer demand data, supplier capacity, products costs, storage costs and transport costs.

In this methodology there are three main steps: receiving raw data, analyzing using excel spreadsheets, and providing outputs.

2.5 Data Processing Phase

In the data processing stage, the objective function, set, decision variables, parameters, constraint functions, and validate the model. The main purpose of this study, which is optimization results: total system cost, total delivery days, utilization of warehouses, and utilization of manufacturers.

In this study Mixed Integer Linear Programming (MILP) method is used to conduct the data.

2.6 Limitations

Due to limited public data on the distribution of fuli and lubricants in this study there is raw statistics of fuel and lubricant production, distribution and consumption made by the US Energy Information Administration's SEDS database and company websites. That means there is no primary data provided in this paper, all data comes from secondary data sources.

The other challenge that needs to be mentioned in this study is forecasting logistic demand service. There are several issues that need to be mentioned in this area, forecasting demand service is a vast study by itself. It needs a larger time schedule, so due to the time limitations, study only focuses on forecasting truck freight costs.

3. Literature Review

3.1 Concept and Overview of Supply Chain Process

The concept of supply chain management refers to management that covers the conventional tasks of a corporation into a systematic management level, through various suppliers and customers working together for the same goal. In this case it is possible to observe the economic dimension of sustainability in most studies from past to present studies on supply chain. Managing the movement of goods flow and services along the availability chain is mentioned as supply chain management. It also helps determine market trends associated with demand and provide for any goods or services and synchronizes those trends so as to assess an organization's performance (Jaggi & Kadam, 2016).

The availability of supply chain management idea is defined as a philosophy that examines way of integrating activities inside companies so as to satisfy consumer demands in terms of the availability and The difference between integrated logistics and SCM is defined within the last half of the 1990s and at the beginning of the 2000s, therefore the functions of control, coordination, and integration within the management of products flow are assigned as "supply chain management (Mukhamedjanova, 2020). An organized Supply chain network involved within the many processes and activities that generate value within the sort of products, transportation service from one supplier to a different and services that are supplied to the ultimate customer through upstream and downstream links (Kain & Verma, 2018). The evolution of supply chain control from the shopping and delivery activities, in addition to the transportation and logistics functions, with a focal point on integration, visibility, cycle time reduction, and streamlined channels.

SCM has gained traction as a tried-and-true management method for long-term profitability and growth during a sort of industries. By specializing in all aspects of the availability chain management process, this might be done to deliver the right amount, quality, and scheduling of products and services to the proper place at the proper time (Ismail & Mohammad, 2022).
The availability of the supply chain is structured by suppliers, manufacturers, distributors, and end users. The basic goal of a supply chain is to meet consumer requests while still making a profit, and upstream and downstream links connect the numerous enterprises involved in the

supply chain, which are then involved in numerous processes and activities that generate value within the sort of goods and services for the last word consumer (Habib, 2011).

In the Nineteen Fifties and 1960s, maximum producers emphasized mass manufacturing to reduce unit manufacturing price because the number one operations strategy, with little product or method flexibility. Sharing methods clients or providers became taken into consideration too volatile and unacceptable (Farmer, 1997). Little emphasis seems to be positioned on cooperative and strategic buyer and provider partnership. The customers commonly appeared as being a provider to manufacturing, and executives paid restrained interest to troubles worried with shopping.

The development of supply chain management in the Nineties practiced great exercise in dealing with company assets to encompass strategic providers and the logistics feature. Supplier performance broadened to encompass extra state reconciliation of fee and first rate considerations. Instead of duplicating non value adding activities, which include receiving inspection producers relied on providers, first rate management via means of buying best from a handful of certified or licensed providers (Inman and Hubler, 1992).

An integrated SCM dedication through all contributors of the value chain. The purchaser can also additionally should overhaul its buying method and combine a dealer's engineering groups and product designers at once into its personal decision making method. Trusting providers can be precise commercial enterprise sense, however for companies can also additionally nonetheless be greater profitable. There are many different pitfalls of SCM, inclusive of conflicting targets and mission, insufficient definition of client service, and separation of supply chain layout from operational decisions (Lee and Billington, 1992)

Incorporate the purchasing and logistics features with different key company features can create an intently connected set of producing and distribution processes. It allows groups to supply services and products to each inner and outside clients in a perfect time and manner. Similarly make the most of the aggressive gain related to incorporated processes.

3.1.1 Deterministic Supply Chain Models

Successful supply chain management requisite many decisions in the operation process. And fall into different phases, relying at the frequency of every selection and the duration over which a selection segment has an impact. Design, planning, and operation of a supply chain have a robust effect on usual profitability and success.

(Geoffrion and Graves, 1974) develop several models for the deterministic supply chain network design problems, on multi-commodity distribution community design. This version became later prolonged to contain greater sensible troubles in production, warehousing, and distribution. Multi-commodity mixed integer linear model design is this version included strategic and tactical decisions. In addition, provided a greater green approach for fixing the large-scale issues the use of the Benders' decomposition algorithm, which incorporates strengthening the dual variables developed by (Dogan and Goetschalckx, 1999). Master problem and sub problem are the main problems of MILP, master problem deals with the integer variables while the sub problem works with the continuous variables obtained in the master problem. Iteratively solve the master and sub problems until the top and lower boundaries are sufficiently reduced. The master problem in the SCND problem is concerned with the integer variables that define the network, while the sub problem is concerned with the continuous variables that describe the actual flow of commodities for the tentative network generated in the master problem.

Incorporated layout of Multi commodity, single-period, deterministic supply chain community has been reconsidered, the version lets in the simultaneous of facilities location and allocation. It integrates the strategic selections regarding center choice with the tactical selections regarding supplier, production, warehouse, and purchaser allocation.

3.1.2 Logistics Services

According to Ching (2001) Logistics, encompasses three types of operations: supply logistics, production logistics, and distribution logistics. The first is the direction for business relationships with suppliers in order to produce products and ensure the quality of raw materials, components, and packaging in order to satisfy customer expectations. Production needs at the lowest total cost possible in the second field, the focus is on the modifications. Applied to the final or finished product's material in order to satisfy the deadline and parameters established. Finally, distribution logistics is in charge of distributing finished goods and displaying them. A satisfactory degree of service and client care.

The operation process of the logistics center is based on logistics links and basic processes. The operation processes and links for distribution centers with diverse functions and commodity distribution will differ, but they will all be based on the same basic processes and make suitable adjustments to the relevant operation links(Yuan et al. 2019). In order to increase the level of refined oil logistics transportation, it is required to develop an ideal scheduling model for completed product logistics transportation. This article discussed product oil logistics. For a range of oil products, transportation scheduling systems. Set up a comprehensive system of product oil logistics transportation scheduling.

When it values the acts of planning, control, optimize profits, and minimize costs, logistics brings together a number of different activities with major participation in any development process. It evolves the expected efficiency and efficacy in this way. Management and logistics have a close relationship. Facilitates the completion of a task with favorable outcomes and complete security. The term "logistics" refers to the process of putting things together raw materials, in-process inventory, and completed goods planning, implementation, flow control, and efficient storage items and related data from point of origin to point of consumption to meet client needs criteria, all inside the same company In a business setting, management is both an art and a science. Engineering for, producing, and distributing manufactured or processed goods to a given area and in a timely manner (MOURA, 2004, p.136).

According to Andrade (2004), the goal of distribution network configuration is to improve customer service levels, reduce costs, improve the quality of services offered to consumers, and improve operational efficiency and effectiveness, allowing for the planning and management of a structure with facilities and their operations. Material and information flows. In this approach, it can be seen how physical distribution works in conjunction with transportation. having a focus on the transfer or delivery of goods and services, which accounts for a large portion of the cost of a business. Product or service that reflects their competitiveness, but it is also necessary to assess the reliability and speed of the product or service. Delivering on time, according to deadlines.

Physical material delivery proves to be a persistent logistical difficulty. It is a strategic decision to define the location and function of storage facilities. It's part of a larger range of alternatives that includes customer service policies, inventory policies, transportation, and production, all of which are aimed at maintaining a positive customer experience. Material and completed commodities flow efficiently throughout the supply chain (LACERDA, 2000).

3.1.3 Logistics Service Provider

According to Krauth et al. (2004) approach Different types of logistics service providers. should be described and classified. Third-party logistics providers (3PL) are frequently mentioned in the context of a manufacturer's long-term outsourcing of logistical activities.

Despite the fact that logistics outsourcing has been around for a long time, it is often restricted to a single logistic function, such as transportation or warehousing. Over the last few decades, providers have expanded their capabilities to include inventory management, fleet management, and other services. These companies typically have long-term contracts with their clients and offer services for a variety of operations or, these providers may progressively build horizontal links in addition to the usual vertical relationships in the supply chain of users. In such circumstances, complementary service providers work together to serve a huge customer. As a result of this horizontal coordination, a fourth-party logistics service provider (4PL) has emerged, in which one provider takes the lead in managing numerous other 3PLs to operate as a single point of contact for the user.

In recent years, third-party logistics (TPL) has gotten a lot of study attention. Despite the rising volume of literature on the subject, there has been very little effort put into synthesizing the current status of TPL research. This document attempts to review the current state of TPL literature.

This study includes a review of the literature on Third-Party Logistics (3PL) selection criteria and procedures. Based on a review of 67 papers published between 1994 and 2013, this study concludes that 3PL selection is empirical in nature and is related to a region/country, industrial sector, and outsourced logistics activities.

High-quality service delivery helps companies build their brands and improves consumer happiness. As a result, both practitioners and academics are concerned about the quality of service provided. Companies must identify and enhance how consumers perceive service quality in order to compete successfully in the future. Companies can differentiate themselves through logistics. Distinguish themselves from their rivals (Leuschner & Lambert, 2016). The quality of logistics services, on the other hand, is determined by comparing consumer expectations and perceptions (Giao et al., 2020). Customers' opinions of quality vary, the factors that influence it must be precisely identified. Depending on the type of the service, service quality has different features (Chaisaengduean, 2019). It is vital to improve the concrete components of the logistics service as well as manage the customer's expectations in order to improve the quality of logistical operations that directly benefit the customers from the products they buy (Gil-Saura et al., 2008).

3.2 Performance Measurement

Selection criteria	Elevance in logistics outsourcing	Reference
Compatibility with the users (CPT)	It refers to the ability of the user and the supplier, as well as their support systems, to collaborate closely in order to achieve some shared goals. It can be classified based on business process characteristics, cultural fit, technology competence, and characteristics of the user's other service providers, among other things.	Andersson and Norrman , Lynch, Thompson, Boyson et al., Mohanty and Deshmukh
Cost of service (CST)	It refers to the entire cost of outsourcing logistics, which should be kept to a bare minimum.	Lynch , Langley et al., Boyson et al., Stock et al., Tam and Tummala
Quality of service (QLT)	On-time delivery, accuracy of order fulfillment, frequency and expense of loss and damage, promptness in responding to customer complaints, dedication to continual improvement, and other factors all contribute to the provider's quality.	Razzaque and Sheng, Thompson, Langley et al., Stock et al.
Reputation of the company (RPT)	A provider's reputation refers to the public's perception of how good they are at meeting the needs of their customers. The reputation of a supplier is quite important when choosing one. This is particularly important during the provider's initial screening.	Lynch, Thompson , Boyson et al.

Long-term relationships (LTR)	Long-term relationships that entail shared risks and benefits ensure that the user and the provider work together. It also aids in the management of providers' opportunistic conduct.	Lynch, Boyson et al., Maltz, Stank and Daugherty.
Performance measurement (PM)	The provision of periodic evaluations of the provider's performance allows the two parties to discover service shortcomings. On-time shipments, inventory accuracy, shipping errors, cash-to-cash cycle reduction, and logistics cost reduction	Bhatnagar et al., Lynch, Langley et al.
Willingness to use logistics manpower (WIL)	The provider's willingness to keep some of the user's logistics personnel who would otherwise be laid off once the outsourcing contract ends eliminates the possibility of sabotage. It also increases the user's perception of the provider.	Razzaque and Shen, Ackerman
Flexibility in billing and payment (FBP)	Billing and payment terms that are flexible boost the user's and provider's goodwill.	Bradley
Quality of management (QM)	The provider's capable management may not only deliver excellent service to the user, but also develop a long-term relationship between the user and the provider.	Andersson and Norrman, Lynch, Boyson et al.
Information sharing and mutual trust (INF)	Mutual trust-based information exchange between the user and the supplier is required not only for the agreement's continuation but also for the service's continual improvement.	Lynch, Stock , Bagchi and Virum

Operational performance (OP)	Delivery performance, performance-monitoring capabilities, statistical data reporting to the customer, fault diagnosis capability, detailed accounting information, system security, timeliness, confidentiality of sensitive data, and so on are all indicators of a good provider's operational performance.	Langley et al., Tam and Tummala
Information technol- ogy (IT) capability	A provider's sophisticated IT skills aid in the reduction of uncertainty and inventory levels. Users may be able to exploit advanced IT skills provided by providers in some instances. The user organizations do not need to invest in extensive IT skills merely to track goods and raw materials in these circumstances.	Andersson and Norrman, Lynch, Langley et al., Boyson et al., Langley et al. , Rabinovich et al., Closs et al., Babbar and Prasad
Size and quality of fixed assets (FA)	It contributes to effective operational performance. A plus feature for the provider is the availability of high-quality assets (such as air-conditioned warehouses and trucks) that meet the user's needs.	Boyson et al., Hum
Experience in similar products (ESP)	The user benefits from the provider's prior experience with the user's product range.	Razzaque and Sheng, Ackerman., Richardson, Harrington
Delivery performance (DP)	For user satisfaction, two characteristics of DP, namely "speed" and "reliability," are critical.	Stock et al., Gattorna and Walters

Employee satisfaction level (ESL	It's crucial since the presence of disgruntled personnel at the provider's end can lead to strikes, lockouts, sabotage, and other unwelcome behaviors, all of which can harm logistical operations.	Lynch, Boyson et al., Langley et al.
Financial performance	A provider's strong financial performance ensures service continuity and continuous upgrades to the equipment and services utilized in logistics operations.	Andersson and Norrman, Boyson et al., Gattorna and Walters
Market share (MS	The provider's market share is based on its financial success,reputation and customer satisfaction.	Thompson
Geographical spread (GS) and range off ser vices provided (RS)	A wide geographic spread and range of services given by the provider are desirable since they increase market access and provide the user with many more options. The provider's large GS and RS may also allow the user to save money on distribution and marketing of the products.	Boyson et al., Maltz, Bradley
Risk management (RM)	It refers to the provider's capacity to deal with any unforeseen issues. It is required to maintain the services' continuance.	Boyson et al.

Surge capacity of provider (SC)	It becomes critical if the user's logistical requirements increase as a result of a sudden increase in product demand.	Anonymous

Clause for arbitration and escape (CAR)	The prospect of a conflict between the user and the provider cannot be ruled out in the long run. As a result, it is vital to provide a CAR that is acceptable to all sides.	Richardson
23. Flexibility in oper ations and delivery (FOD)	Flexibility in operations and delivery may allow the user to provide personalized service to its clients, especially in the case of extraordinary or unusual requests.	Stank and Daugherty

Table 1 Performance Measurement

3.3 Logistics Distribution

The system by which items and services are transported from manufacturers to end users is known as the distribution channel. The distribution channel's goal is to connect the manufacturer of a product or service to the end consumer in this fashion. It refers to the distribution channel as a collection of external agents from a managerial standpoint. Involved in the production and distribution of goods and services for use and consumption in this way, it emphasizes the significance of logistics, particularly product distribution to customers. Organization. This includes petroleum based fuels.

Ballou (2001) defines distribution logistics or physical distribution as a part of the logistics business that is responsible for the handling, storage, and order processing of the company's final products, noting that this activity is the most important in terms of logistics costs for most organizations. The most important goal of physical distribution is to ensure that the products reach the client or consumer in good condition. Service desired at the cheapest price (Novaes, 2001).

3.3.1 Transport Logistics

The actions of transport logistics in cargo movements between the product's origin and the consumer are documented. Despite a simple overview, there is a level of operational complexity when it comes to the considerations that must be made about the stuff to be taken away, the route, time, security, and transportation. Type, as well as other factors.

Caixeta Filho and Martins (2001), Considering the notion of cargo loads, it is worth noting that transportation research has been established in a variety of fields and is crucial to the logistics industry, where transportation is usually the most important factor, accounting for one to two thirds of logistics costs. As a result, the movement of commodities, routing, and utilization of the vehicles' operational capabilities are all part of transportation.

3.3.2 Delivery Pattern

The logistics and transportation industries are expanding at a rapid pace, aided by a strong technological evolution. The explosion of the e-commerce business, fueled by ubiquitous internet access and growing developments in new delivery techniques, has resulted in a year-over-year increase in the amount of goods to be delivered by various corporations. In 2019, for example, the average number of packages shipped in China was roughly 63.5 billion packets. Furthermore, in 2019, the average amount of shipped parcels every second around the world was 3248. Furthermore, by 2026, the present amount of parcels worldwide is predicted to increase to between 220 and 262 billion packets. Consumer expectations, on the other hand, have risen; they now demand things purchased online to be delivered as quickly as feasible and at the lowest possible cost. As a result, the freight prices that enterprises must incur to transport products to houses are steadily rising year after year, as more and more parcels must be delivered to addresses scattered around the city deliveries that must be made in the same region. To recognize the optimization method taken on this work, bear in mind for a second a single supply of herbal fuel lines and an unmarried vacation spot in which herbal fuel lines have to be introduced to deal with a positive intake rate. During the time taken via way of means of this vessel to go back to the herbal fuel line supply, get a brand new load, and tour once more to the transport web page to renew offloading, there have to be sufficient fuel line to be had on the Transport web page to deal with the intake rate.

A not unusual place quandary shared with the aid of using the IRP papers indexed above is their awareness on transportation and stock costs, whilst neglecting the consequences on DC operations and instore operation costs. Furthermore, maximum packages of IRPs are within the context of vendor-controlled stock, wherein the transportation community is now no longer owned with the aid of using the retailer (Gaur & Fisher, 2004).

Ronen and Goodhart (2008) suggest a hierarchical method to resolve the shipping making plans hassle on a tactical level. First, the authors cluster shops with similar traits and preselect styles. They then assign styles to shops the usage of an MIP. Finally, they use a PVRP to build transit routes.. Feedback loops aren't integrated, which causes the hassle that after styles are assigned to the shops they cannot be modified any extra despite the fact that the routing step can also additionally reveal that adapting the shipping styles may want to seiz.

The logistics and transportation industries are expanding at a rapid pace, aided by a strong technological evolution. The explosion of the e-commerce business, fueled by ubiquitous internet access and growing developments in new delivery techniques, has resulted in a year-over-year increase in the amount of goods to be delivered by various corporations. In 2019, for example, the average number of packages shipped in China was roughly 63.5 billion packets. Furthermore, in 2019, the average amount of shipped parcels every second around the world was 3248. Furthermore, by 2026, the present amount of parcels worldwide is predicted to increase to between 220 and 262 billion packets. Consumer expectations, on the other hand, have risen; they now demand things purchased online to be delivered as quickly as feasible and at the lowest possible cost. As a result, the freight prices that enterprises must incur to transport products to houses are steadily rising year after year, as more and more parcels must be delivered to addresses scattered around the city deliveries that must be made in the same region. To recognize the optimization method taken on this work, bear in mind for a second a single supply of herbal fuel lines and an unmarried vacation spot in which herbal fuel lines have to be introduced to deal with a positive intake rate. During the time taken via way of means of this vessel to go back to the herbal fuel line supply, get a brand new load, and tour once more to the transport web page to renew offloading, there have to be sufficient fuel line to be had on the Transport web page to deal with the intake rate.

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Ronen and Goodhart (2008) suggest a hierarchical method to resolve the shipping making plans hassle on a tactical level. First, the authors cluster shops with similar traits and preselect styles. They then assign styles to shops the usage of an MIP. Thirdly, they construct transportation routes applying a PVRP. Feedback loops aren't integrated, which causes the hassle that after styles are assigned to the shops they cannot be modified any extra despite the fact that the routing step can also additionally reveal that adapting the shipping styles may want to seize additional financial savings Furthermore, Ronen and Goodhart (2008)'s version ignores expenditures for store operations. Store logistics, however, constitute the principle price block of operational logistics charges in step with several studies (Kuhn & Sternbeck, 2013; van Zelst et al., 2009) and account for about 50 percent of general logistics charges.

According to (Sternbeck M.G. and Kuhn H, 2014) Selects shipping styles for shops on the premise of a hard and fast selection of preselected affordable styles, mutually thinking of DC, transportation and shop operations. This model, however, assumes that logistics carriers satisfy all shop deliveries. Thus, transportation fees most effectively depend upon the gap among the DC and the shop and the related delivery volume. Bundling consequences throughout shops because of joint excursions aren't taken into consideration, despite the fact that those can extrude the answer significantly, that is illustrated in Fig. 2 In which shops A and B are assumed to be placed near each other.

Example I of Fig. 2 suggests feasible shipping styles for shops A and B; shop a gets deliveries on days 1 and four, and shop B on day 2 most effectively. This may be the minimal price solution if transportation fees are taken into consideration to be volume- and distance established most effective. However, shop A and B may be provided on the equal tour, which may also have a useful impact on overall fees if shop B additionally gets its deliveries on day 1 and in all likelihood on day four too (see Example II of Fig. 2). In this case, a better shipping frequency for shop B (i.e., shop B gets an extra shipping on day four) consequences in transportation price financial savings and decreased store handling, which compensates for extra efforts inside the DC. Fig. 2. Example

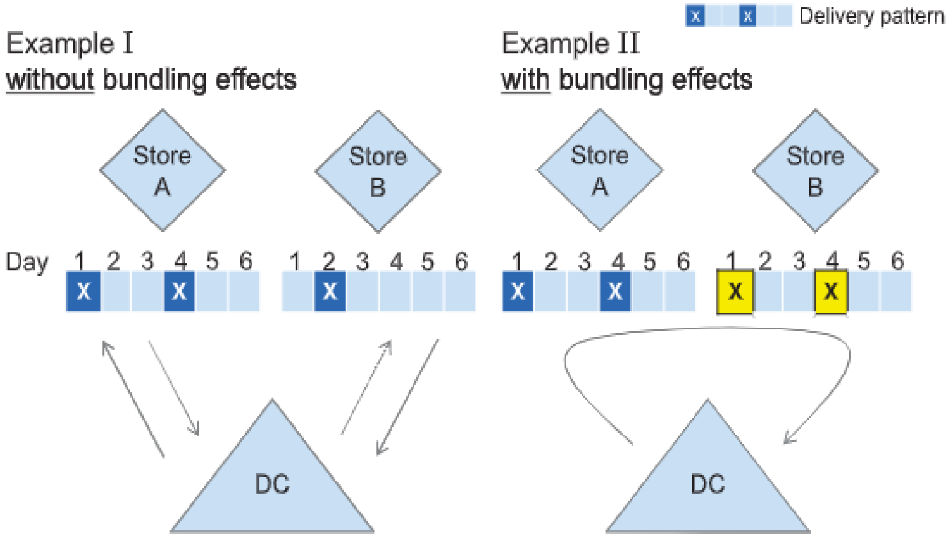

Figure 2, Example 2

Changes in the delivery decision when bundling effects across stores are considered.

Given the putting and fee shape with inside the DC, transportation and keep, the choice trouble desires increasing in order that it takes into consideration all applicable fee results confronted via way of means of a store that orchestrates the complete achievement process. We make a contribution to the current literature of keep shipping making plans via way of means of designing and fixing a complete making plans technique to decide keep shipping styles that consists of transportation troubles across shops in addition to charges and ability in every operational subsystem without preselecting styles in advance. In the subsequent section we increase a greater specific choice help version for shops to pick out gold standard shipping styles for his or her shops.

3.3.3 Warehouse Management

The warehousing function is critical in a supply chain because it acts as a node in connecting material flows between the supplier and the client. Companies are constantly driven to improve their warehouse operations in today's competitive market climate. Many organizations have also tailored their value propositions to improve customer service levels, resulting in shifts in warehouse roles. This article summarizes the findings of a study conducted to assess performance levels and increase productivity in manual warehouses through the development of a WMS framework and a cost-benefit analysis.

A warehouse is a location in the supply chain where products are consolidated to save money on transportation, obtain economies of scale in manufacture, or save money on purchases. (Hackman ST, 2006). Warehousing has also been identified as one of the primary processes through which businesses can give customized services to their clients while gaining a competitive edge.

Warehousing takes up to between 2% and 5% of the cost of sales of a corporation.(Heung Suk Hwang, Gyu Sung Cho ,2006) Moreover, in today's highly competitive global business world, firms place a premium on Return on Assets, therefore reducing warehousing costs has become a critical business concern. Many companies are automating their core warehousing processes in order to achieve the higher throughput rates or inventory turns that are required for their warehousing operations to be profitable.

There are two types of warehouses in terms of warehousing activities: dedicated and public warehouses. Dedicated warehouses are often created in collaboration with the shipper and are based on a long-term contract. This enables processes to be organized and information systems to be designed in such a way that they seamlessly connect with the shipper. The level of automation is extremely high, allowing for efficient commodities handling. The logistics service provider may also serve as the shipper's call center. On the other hand, public warehouses service an average of five consumers. The warehouse is built independently of the logistics service provider's customers. The relationship is frequently described as temporary, and the amount of process integration and automation is far lower than in specialized warehouses. A logistics service provider's connection with his client can also be classified based on whether an open book or closed book method is used. The price of a closed book arrangement is normally negotiated once a year and does not vary during that period. In an open book environment, however, the logistics service provider and his customer review the cost situation every month. If it is discovered that late shipper notifications, for example, resulted in a cost rise, the pricing can be adjusted accordingly.

(Faber et al, 2002). Examine warehouse management information systems. They look at the complexity of warehouses and control structures in their exploratory study. The volume and heterogeneity of handled products, the extent of overlap between them, the amount and kind of technology, as well as the features of connected operations, all contribute to the complexity of warehouse management. Their five findings show that customized software will best support warehouses with a large daily amount of processed orderliness and stock holding units. At the strategic, tactical, and operational levels, warehouse design problems and concepts are addressed by (Rouwenhorst et al, 2000).

(Gu et al, 2007) propose a taxonomy of warehouse operation planning based on the core warehouse functions of receiving, storage, order selection, and shipping and provide some comments on warehouse design in 2010.

3.3.4 Warehouse Strategic And Tactical Decision

The strategic and tactical choice and evaluation of a sustainable warehouse are linked to several study subjects and approaches. AGVs and shuttles in warehouses can achieve increased flexibility and efficiency in throughput, as well as a lower environmental effect, when compared to traditional crane-based systems. (In Tappia et al, 2015), the indicators

for comparing AS/RS to AVS/RS are energy usage and environmental effect. AVS/RS can attain a win–win situation in terms of economic and environmental performance, according to the findings. A correct storage assignment can enhance picking efficiency and reduce energy consumption for the tactical decision of the sustainable warehouse. (Li et al, 2020) present a KIVA warehouse turnover rate-based decentralized storage policy, followed by an energy-consumption-aware storage assignment evaluation approach.

3.3.5 Warehouse Operational Decision

Various strategies, such as sequencing, scheduling, and power load management, can be used to achieve the sustainable aim in warehouse operational decisions, according to the literature examined. In the sustainable warehouse, the win–win of environmental and operational goals can be fulfilled to some extent since removing unnecessary work can enhance efficiency while lowering energy consumption. Other issues related to sustainability, such as the design and operation of reverse logistics warehouses, have yet to be resolved. Social and human elements are also potential targets for warehouse sustainability. Human variables in the typical warehouse order picking process have been studied by several academics. E (Grosse et al., 2017; Glock et al., 2019).

From a human-centric standpoint, smart warehouse adoption and operation remain possible opportunities and constraints. The performance of technology adoption may be influenced by management skills, mindsets, and other human variables (Mahroof, 2019). The impact of human factors on smart warehouse operations management can be explored further in future research. Information interconnection: IoT and CPS raise the issue of information interconnection, which is a relatively new issue in warehouse operations. IoT, CPS, and other developing interconnection technologies improve data exchange within the warehouse system and throughout the logistics chain. Other developing technology, such as sensors and smart things, should be investigated for use in warehouse operations.

Figure 3 Warehouse operation

3.3.6 Warehouse Strategic Decision

When it comes to journey time in strategic warehouse design, system features must be considered because they have a direct impact on the system's overall performance. Various warehouse systems may have different unique qualities. In this section, we'll look at the impact of system features such as movement characteristics, command cycle, battery charging for RMFS and AGV systems, and picking station efficiency.

Acceleration/deceleration and the speed of the storage/retrieval (S/R) machine are two movement characteristics that might directly influence the real trip duration, especially in the case of frequent start and stop. The speed profile is a key influencing aspect of optimal storage rack design when considering acceleration/deceleration. (Yang et al., 2015b). The RMFS design can be influenced by the robot's driving behavior. Lamballais Tessensohn et al. (2017) develop a model for evaluating warehouse architecture features of RMFS while taking robot driving behavior into account. The position of the workstations has a significant impact on maximum order throughput, although changing the length-to-width ratio of the storage area has a minor impact.

The command cycle is a notion that describes how warehouse systems operate. There are two types of command cycles that are often used: single command cycle (SC) and multiple command cycle (MC). DC stands for dual command cycle (Pan and Wang, 1996). In

Washington, D.C. The storage and retrieval actions, as well as the operation mode, are all included. Within the context of a movement DC will produce greater results. In the majority of cases other forms of operation, such as Xu et al. (2015) proposed the quadruple command cycle. Previous research has looked into this. The impact of command cycles on system settings has been studied in some studies (Salah et al, 2017). The command cycles may have different meanings for different AS/RS variations. For managing too big goods like containers, split-platform automated storage and retrieval systems (SP-AS/RSs) are used.

Workstation handling speeds may have an impact on warehouse architecture and operation. To get a better robot assignment for online retailers, Zou et al. (2017) created a model with a neighborhood search algorithm. To evaluate the proposed assignment rules, semi open queueing network models and an estimated two-phase technique are presented. Furthermore, based on the analyzed assignment criteria, the suitable size of shelf blocks is designed.

3.4 Material Handling

Stephens and Meyers in their book "Manufacturing facilities. Design & Material handling" define the material handling as "the function of moving the right material to the right place, at the right time, in the right amount, in sequence, and in the right position or condition to minimize production costs" (Stephens and Meyers 2013).

The material handling has five dimensions:

- Movement: involves the actual transportation or transfer of material from A to B. The prime concerns here are efficiency and safety.
- Quantity: dictates the type of equipment needed and the cost
- Time: determinate how quickly the material can move through the facility
- Space: is concerned with the space required for the storage of the equipment and the movement of the material
- Control: some aspects of the control dimension are tracking of the material, Positive identification and inventory management (Stephens and Meyers 2013)

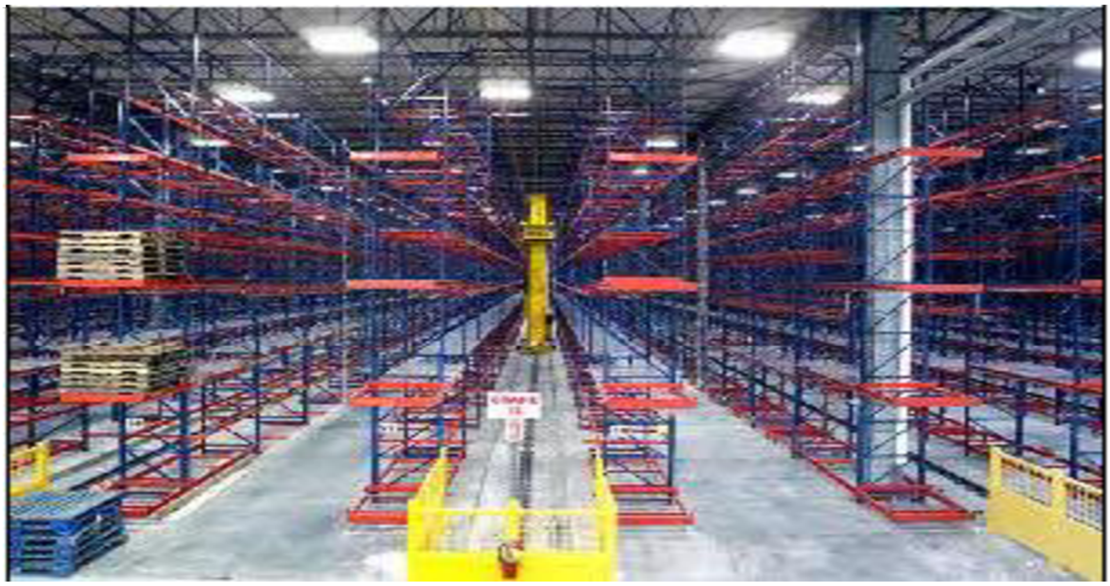

Figure 4 material handling Global Intra Logistics solution service

Figure 5 material handling Global Intra Logistics solution service

Figure 6 material handling

Material handling has five dimensions source Global Intra Logistics solution service

Figure 7 Handheld forklift truck

Figure 8 Toyota forklifts, 202

3.5 Industry Overview

According to Ross (2018), manufacturers in this industry produce petroleum products such as blended motor oils, brake fluids, lubricating grease and other oil-based additives. Key customers are automobile manufacturers, wholesalers and automotive retail chains.

Figure 9 supply chain US. Source: IBIS World

The lubricant industry can benefit from the rising average age of the vehicle fleet and the number of vehicles. There is an increase in the average age of the US's automobile fleet to 11.6 years (IHS Markit, 2016). Due to vehicle age, the lubricant oil becomes more critical for engine health and maintenance. As a result, the industry revenue can increase even though there is a decline in crude oil prices. According to Ross (2018), there was also a fluctuation in terms of international trade for the industry. Exports are forecasted to decline at the annual growth rate of 5.9% to $47.4 million due to the rising demand in emerging markets. However, the imports are estimated to decrease at an annual growth rate of 22.2% to $236.9 million due to the increasing domestic production.

Year	Revenue $ million	Growth %
2020	22,730.80	1.50%
2021	23,080.90	1.50%
2022	23,439.50	1.60%
2023	23,809.50	1.60%

Table 2 Lubricant Industry Revenue Outlook. Source: IBIS World.

There will be an increase of demand in the future. The industry profitability remained stable in the past five years because of the steady demand for petroleum products and favorable crude oil prices (Ross, 2018, Industry Performance).

The Consumption of F&L, Regarding lubricant consumption and expenditure estimates in 2022 (table 2), the US Energy Information Administration (EIA) estimated that national lubricant consumption was 289.5 trillion Btu (9.88% of US Total).

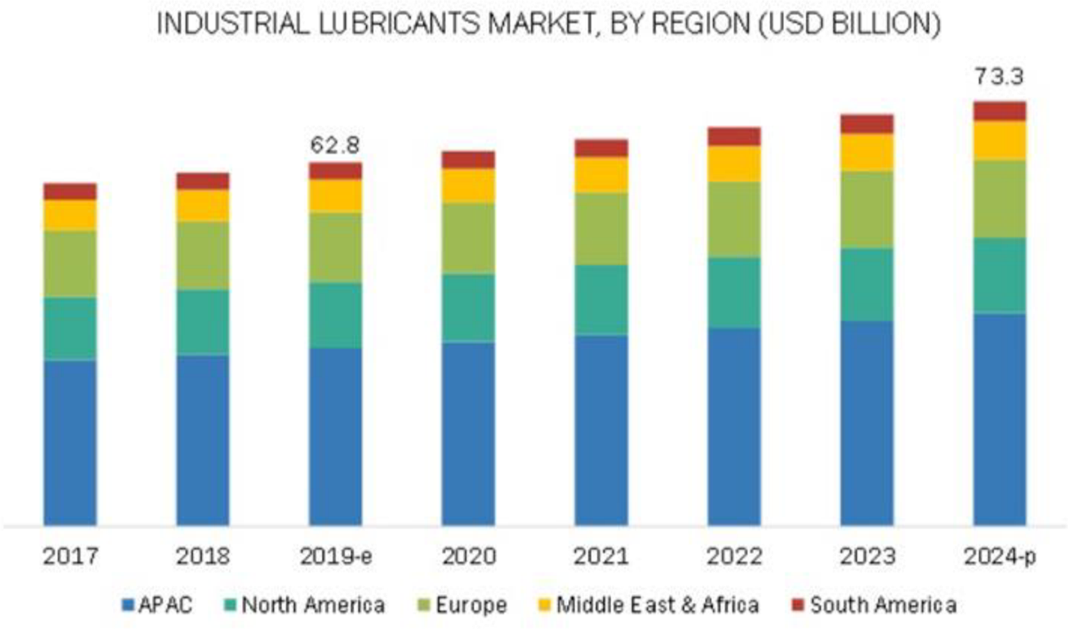

Figure 10 Market-Reports/industrial-lubricants-market

3.6 Forecast Logistics Demand

Short-term forecasting approaches include time series forecasting and regression analysis. We must uncover explanatory factors in regression modeling. have theoretical connections to predicted output Babcock et al. (Babcock et al., 1999).

There are now just a few useful rules for identifying NN structures. A significant job in this project is determining the number of input and concealed nodes. the forecasting of NN time series Normally, the best option is Performance-based architecture can be found.
Some holdout data sets were compared (Zhang et al., 2005). In general, data sets are separated into three sections as follows: There are three types of sets: training sets, validation sets, and test sets. Model estimation, model selection, and model evaluation Neural networks are a computer model that resembles the human brain in that a large number of basic units work in parallel with no centralized control unit. In neural networks, the weights between the units are the fundamental mechanism of storing information over time. The most well-known and easiest-to-understand neural network is the feedforward multilayer neural network. It has one or more hidden layers, as well as an input layer and a single output layer. The following features distinguish deep learning networks from feed-forward multilayer networks in general:respectively, performance evaluation

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- Automatic feature extraction
- More neurons than previous networks
- More complex ways of connecting layers

4 Practical Part

4.1 Overview of the Proposed Model

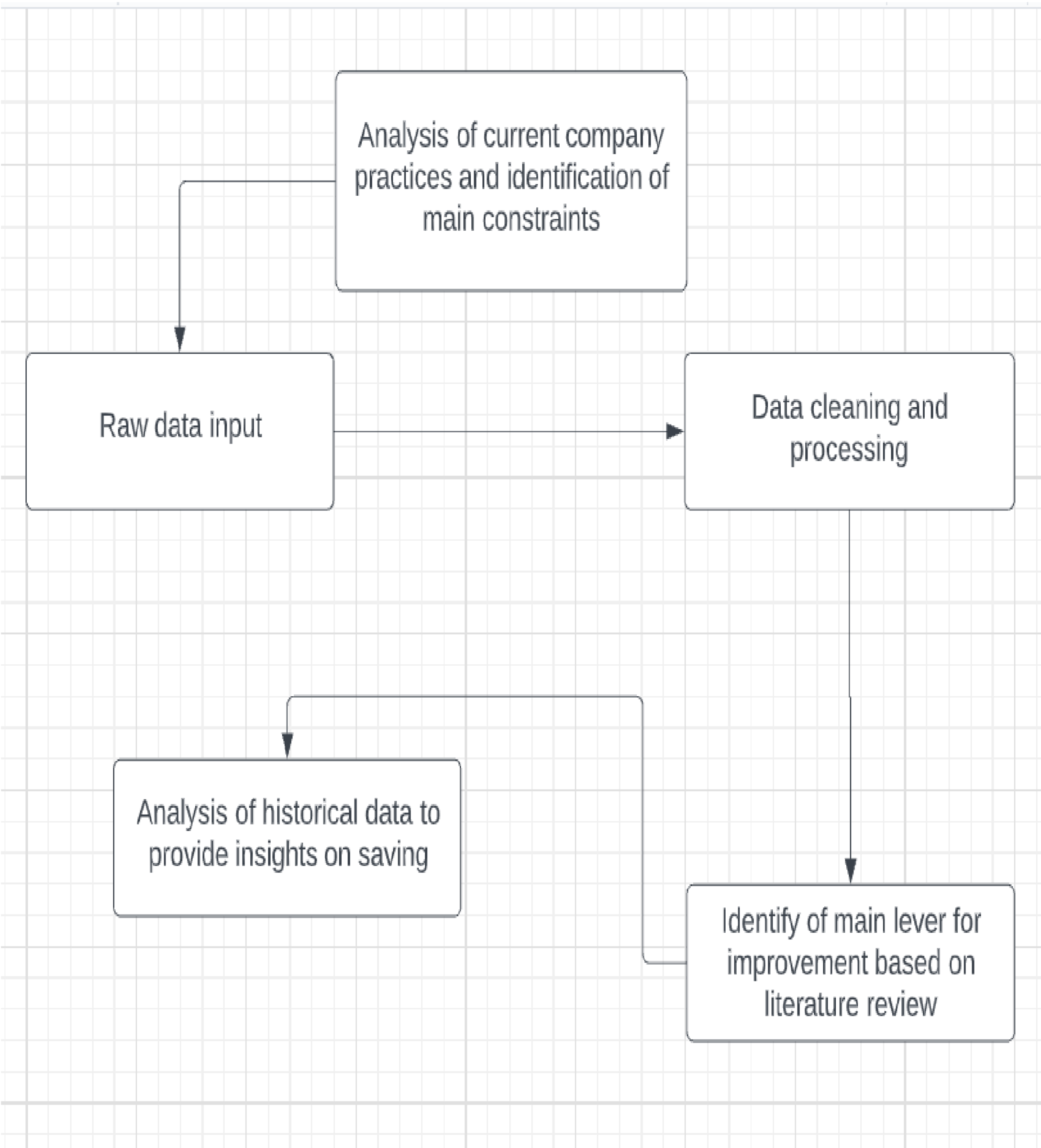


Figure 11 Overview of the Proposed System Source [own]

4.2 Analyse the Current Company Practices

Baytown refinery is one of the biggest refineries of ExxonMobil, its Area activities are located about 25 miles east of Houston, on approximately 3,400 acres along the Houston Ship Channel. Up to 584,000 barrels of crude oil can be processed each day at the refinery.

The site sits within the larger ExxonMobil Baytowncomplex, and includes two facilities referred to asBTEC-East and BTEC-West with 740,000 square feet of space for laboratories, offices, product and applications testing and pilot plant operations. 3,400 acres along the Houston Ship Channel, about 25 miles east of Houston, with a refinery, chemical plant, and olefins plant.

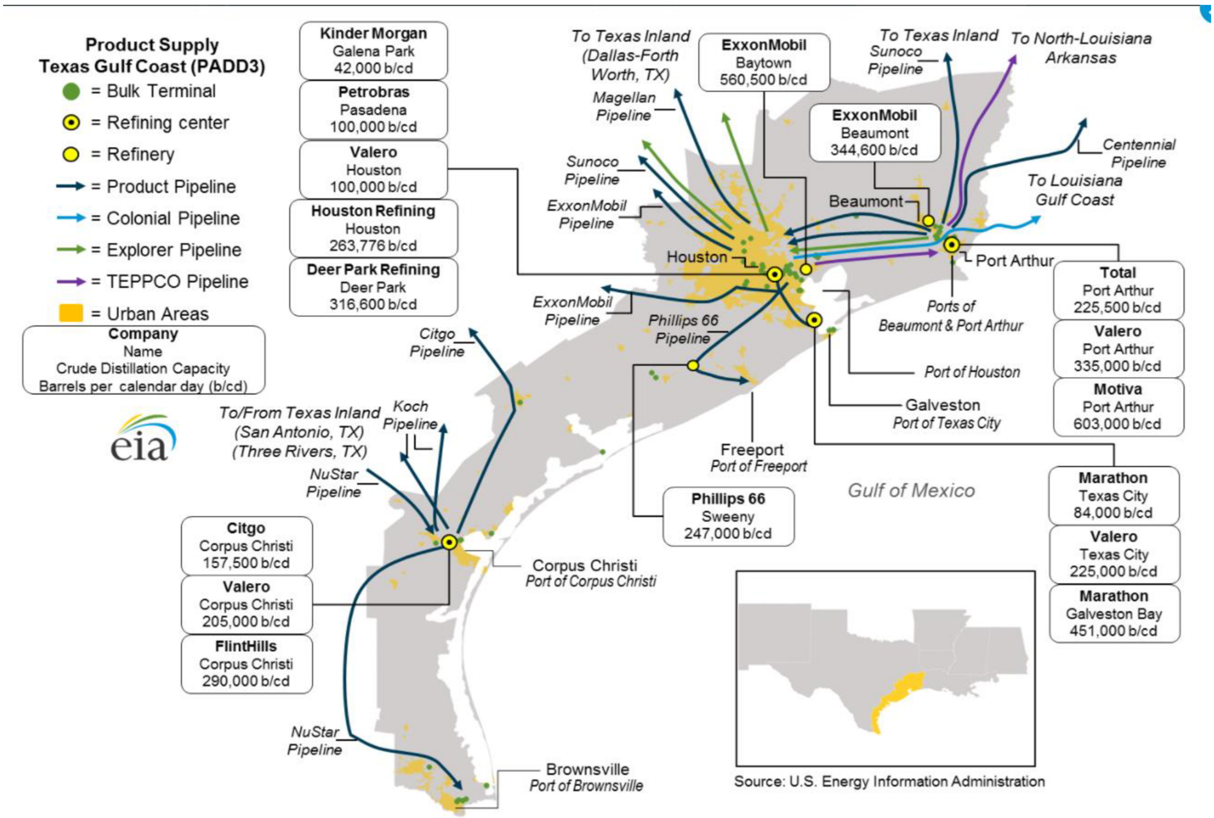


Figure 12 Refining Capacity map 2020, source ExxonMobil

Global Spend by Category Families ($M) of 24 months report

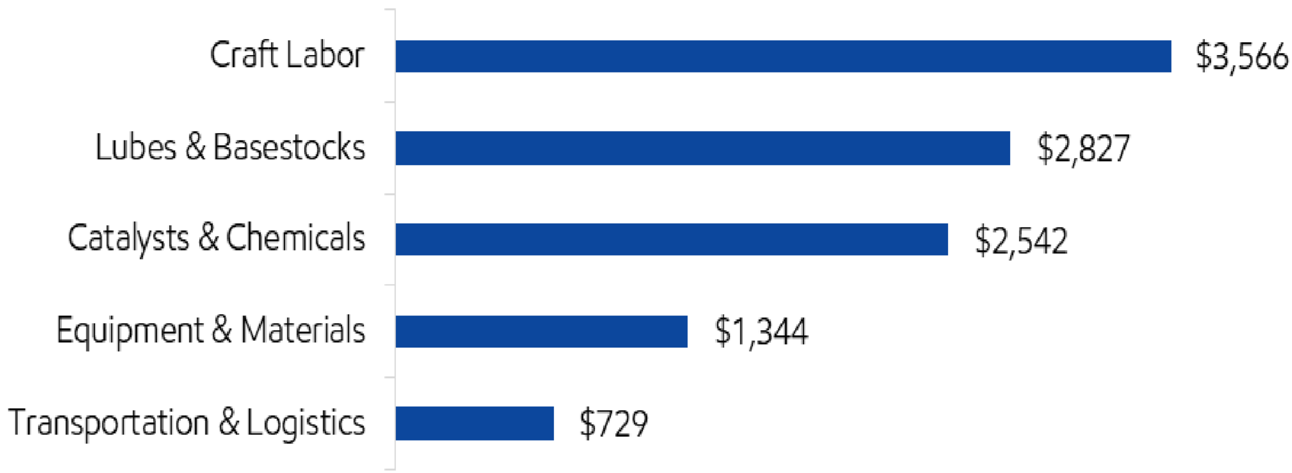


Figure 13, ExxonMobil annual report 2021

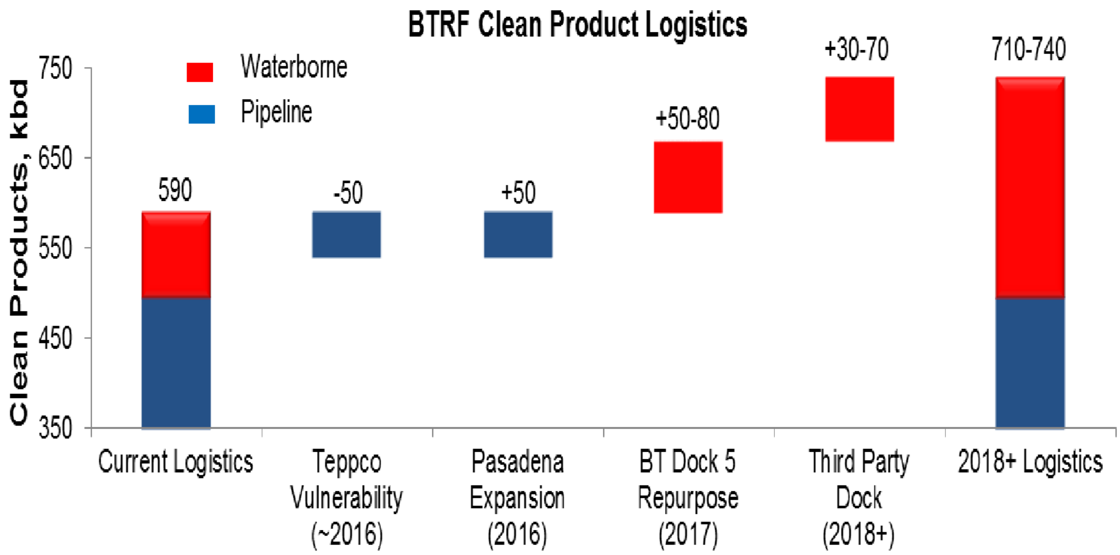


Figure 14 Products Logistics Outlook

Supply disruptions create significant volatility due to geographic isolation from major supply sources and stringent mogas specs With demand decline and potential rationalization, market shorts will become increasingly valuable over the next 10 years.

SWOT - points to relative strength of distributor in inventory and logistics; challenges in Sales and Marketing Opportunities to reinforce strengths; EM approach must be mindful of emergent models.

Distributor Network SWOT	
Strengths ·Mobil-aligned network & customers who value the Mobile brand ·National geographic coverage (people & infrastructure) which meets National Account, Strategic Global Account needs ·Strength in B2B ·Efficient operators (inventory, logistics)	**Weaknesses** ·Current Mobil product offer does not meet full breadth of distributor opportunities (e.g. PVL Offer ex-Mobil 1, Heart of Market, Aqueous Coolants [Water-based MetalWorking Fluids], Food Grade) ·Mobil digital offer lags other IOCs, e.g. Shell distributor order automation ·Sales expertise and Marketing competencies ·Brand alignment expectations limits distributor growth optionality (misaligned interests)
Opportunities ·Through stronger integration, distributor people, infrastructure to serve as a force multiplier in 1) last-mile distribution 2) local manufacturing/ packaging, 3) local sales, engineering, mktg support ·Aligned "One Team" network approach enables stronger collaboration, synergies, shared services ·Growing component in services (DLEs?) ·New business models/ownership structures ·Varied capability to effectively deliver to last mile	**Threats** ·Emergent private label products/services could diminish Mobil branded product differentiation Non-traditional channels (Amazon) ·Distributor consolidation trends have been yielding diminishing customer service levels ·Potential BCP threat of large distributors ·Larger distributors rely on significant non-Mobil lubes activity to drive growth objectives (Chemicals, Fuels, House Brand)

Table 3 SWOT

The problem to be solved was to optimize F&L distribution logistic network. Among the different Most of the customer zones are located close to the distribution centers. Network optimization models (facility location, mode, and network flow)

4.3 Optimal Design of Products Distribution Network

The objective of optimization strategy is to show the specific product flow from the plant through the warehouse to the market area without violating both plants production capacity constraint and satisfied market area demands and that optimize the total distribution of cost. There are three steps in formulating a Linear program. First we need to define the decision variables, Write the objective in terms of these decision variables and Write the constraints in terms of these decision variables. Mixed Integer Linear Programming (MILP) method is used to create mathematical models and to achieve research objectives.

4.3.1 Notation

The notation to be used in this section is described below,

A. Sets

A = destination agent

P = delivery period

I = product

v = vehicle

K = possible distribution centers

L = customer demand zone

J= Plant

B. Parameter

n= number of point

dij = distance from point i to point j

dij= demand of client

C = capacity of truck

Xjk= 1 if production plant j is assigned to distribution center k, 0 otherwise

Xkl= 1 if distribution center k is assigned to customer zone l, 0 otherwise

Wij= 1 if production plant j is to produce product i, 0 otherwise

Q_{jk}^{min} = minimum/maximum rate of flow of

Q_{jk}^{min} = materials transferred from plant j to distribution center k

Q_{k1}^{min} = minimum/maximum rate of flow of

Q_{k1}^{min} = materials transferred from distribution center k to customer zone l

C. Variables:

xij = is one truck goes from node I to node j (binary)

fij = number of units in a truck going from node I to j

$X1avp$ = Volume of shipment in vehicle V in period P for WH 1

4.3.2 Network Structures Constraints

A link between a production plant j and a distribution center k may exist only if production plant j is established:

$$X\,jk \;\; \leq Y\,j\,; \quad \forall, k \tag{4.1}$$

If a distribution center k is established, it can then be served by more than one production plant j

$$\sum_{j} X_{jk} \geqslant Y_k, \quad \forall k. \tag{4.2}$$

This constraint can be transformed into a single source constraint for cases where this restriction applies. In this case the constraint has to be written as

$$\sum_{j} X_{jk} = Y_k, \quad \forall k. \tag{4.3}$$

Distribution center k and a customer zone 1 may exist only if the distribution center is established

$$Xk1 \;\; \leq Y\,k\,; \quad \forall k, 1. \tag{4.4}$$

Each customer can be supplied by more than one distribution centres to satisfy demand:

$$\sum_{k} X_{kl} \geqslant 1, \quad \forall l. \tag{4.5}$$

4.3.3 Logical Constraints For Transportation Flows

The flow of material from production plant j to distribution center k can take place only if the corresponding connection exists:

$$Q_{jk}^{\min} X_{jk} \leqslant \sum_{i} Q_{ijk} \leqslant Q_{jk}^{\max} X_{jk}, \quad \forall i, j, k$$

(4.6)

$$Q_{kl}^{\min} X_{kl} \leqslant \sum_{i} Q_{ikl} \leqslant Q_{kl}^{\max} X_{kl}, \quad \forall i, k, l \qquad (4.7)$$

Define the decision variables for $i = 1, 2, 3, 4, \quad j = 1, 2, 3.$

$$\text{xij} = \{1, If\ warehouse\ j\ serves\ client\ i\ 0, Otherwis \qquad (4.8)$$

$$\text{yj} = \{1, if\ warehouse\ j\ is\ established\ \ 0, Otherwise \qquad (4.9)$$

$$Min \sum_{i=1}^{n} \sum_{j=1}^{n} dijxij$$

$$\sum_{j=1}^{n} xij = 1 \quad \forall i = 2, \ldots\ldots, n$$

$$\sum_{i=1}^{n} xji = 1 \ \forall = 2 \ldots\ldots, n$$

$$\sum_{j=1}^{n} fji - \sum_{j=1}^{n} fji = Di \quad \forall = 2, \ldots, n$$

$$0 \leq fij \leq cxij \quad \forall i, j = 1, \ldots\ldots, n$$

$$xij \in \{0,1\} \quad \forall i, j = 1 \ldots \ldots, n \qquad (4.10)$$

Objective function which is logistics distributions costs consisting of transportation or shipping logistics costs and storage costs. Storage cost is the result of multiplying the total volume of product demand with the storage cost per product order volume. (4.11)

$$\sum_{v} X1vpa = vapa \quad \forall a, p$$

To ensure the delivery volume to the customer in the delivery of vehicle V in period P may not be less than the volume of the request by customer of shipment A in period P.

$$\sum_{v} X1_{vpa} \quad \leq \quad S1_{v} vv_{v} \quad \forall_{a,v} \qquad (4.12)$$

To ensure the volume of vehicle V delivery does not exceed the volume capacity of vehicleV.

4.3.4 Outsourcing And Distribution

The objective is to find a distribution strategy that shows the flow of products from the plant distributors WHO to customers. In the production of all plants capacity constraint, to satisfy market area demands and that minimizes distribution cost.

4.3.5 Transportation Rate

Is the cost per mile per cost of products sold (COGS) or stock keeping unit (SKU), Class of rates for truck, rail and other trucking companies is an important factor and the rates are quite linear with the distance not with volume. There are two kinds of transportation rates:

- Company owned: It can be easily calculated from information like annual costs per truck, annual mileage per truck, annual amount delivered, and truck's effective capacity.
- External fleet (third-part): More complex calculation is needed

  Transportation costs = Transportation rate × Distance (4.13)

4.3.6 Mileage Estimates:

Once we know the transportation rates, which usually depend on the distance, we need to estimate the mileage between any two locations. Depending on your situation, you want to.

- Exact estimation but this usually can be obtained using GIS (Geographic Information System), but the drawback is cost and speed.
- Approximate estimation: For most of the applications, this will be sufficient.

4.3.7 Warehousing Costs:

- Handling cost: proportional to the amount of material the flows through the warehouse.
- Fixed Cost: All costs that are not proportional to the amount of material the flows through the warehouse. It is typically proportional to warehouse capacity but in a nonlinear way. So warehouse capacity needs to be estimated, obviously the capacity is proportional to the peak inventory, not the average inventory or annual flow.

The concept of inventory turnover ratio, given by:

$$\text{Inventory turnover ratio} = \frac{annual\ flow}{average\ inventory\ level} \qquad (4.14)$$

The warehouse capacity is given by:

Warehouse Capacity =

The impact of aggregate demand: $\sigma 1 + \sigma 2 \geq \sqrt{\sigma 1^2 + \sigma 2^2}$ (4.15)

4.4 Data Collection and Preparation

To show the proposed model the data used in this thesis refers to a period of one month from November 1st to the beginning of December 2021. There is no primary data provided in this paper, all data comes from secondary data sources. There are raw statistics of F&L supply and consumption made by the US Energy Information Administration's SEDS database and outlook 2021 report. After the data are collected and cleaned, ensuring that the data and model accurately reflect the network design problem. This is done by reconstructing the existing network, collected data and comparing the output of the model to existing data

To design optimized distribution logistic network model information used in this study includes.

- Location of customers, stocking points and sources location theory
- Listing of products
- Demand for each product by customer location forecast technique
- Mileage estimation GIS
- Shipment sizes by product and order patterns by frequency, size, and season, content
- Customer service goal

The Logistics Network consists of:

Plants/Vendors or suppliers

Warehouse

Distribution Centers

Customers

Raw materials and finished products

Data Sources	Data Type	Frequency
https://www.eia.gov/dnav/pet/pet_pnp_gp_dc_nus_mbbl_m.htm	Numerical	Yearly
https://www.iea.org/reports/world-energy-outlook-2021	Numerical	Yearly
http://www2.exxonmobil.com/Lubes/about_how.aspx	Qualitative	Yearly
http://abarrelfull.wikidot.com/torrance-refinery	Numerical	Yearly
https://lensonwashington.com/login?ReturnUrl=%2ftariffs	Numerical	Yearly
https://www.bts.gov/product/state-transportation-statistics	Numerical	Yearly

Table 4 Data source

Data required by the model to set values for the parameters. All available data used to produce the results are presented in Sections 4 and Tables 4 –18.

4.5 Delivery Address Guidance

Post Move, the default delivery address will change to the Texas Logistics Center. Anything that goes to the onsite warehouse everyday, purchased by any individual in any group (excluding exceptions), will go to the Texas Logistics Center (Distribution centers)

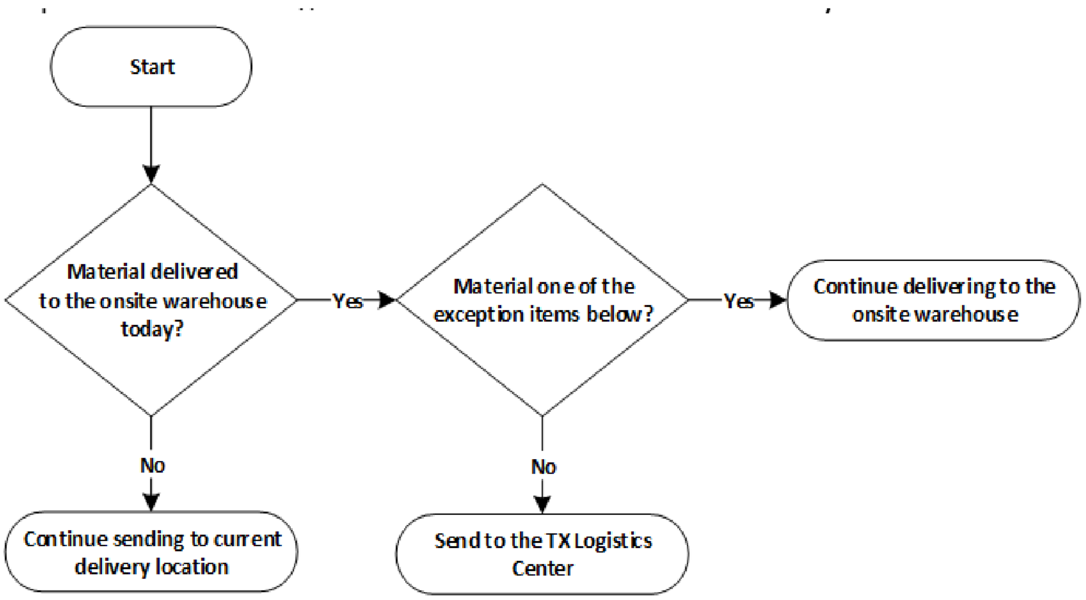


Figure 15 Delivery guidance system Source [own]

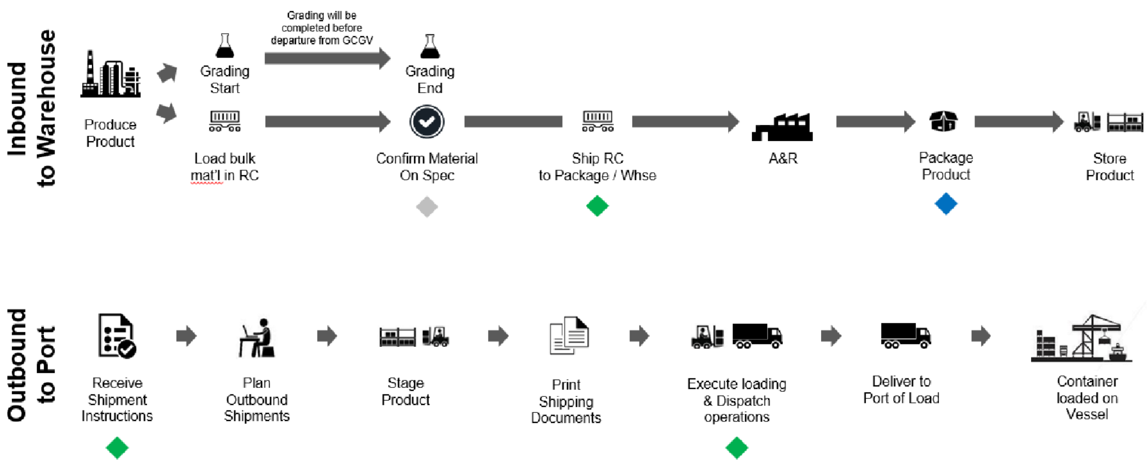


Figure 16 Supply chain flow ExxonMobil reports 2020

4.5.1 Facility Location Problem and Optimization Model.

Figure 11, shows the current flow of products each day from plant to distribution through pipeline and for three of the customers through truck, we can also see the distribution of products from distributors to customers by trucking system. Baytown Refinery has a capacity of 90 (CPU) / 30 (Truck), SF: 23 trucks/day capacity on each rack. 46 total.

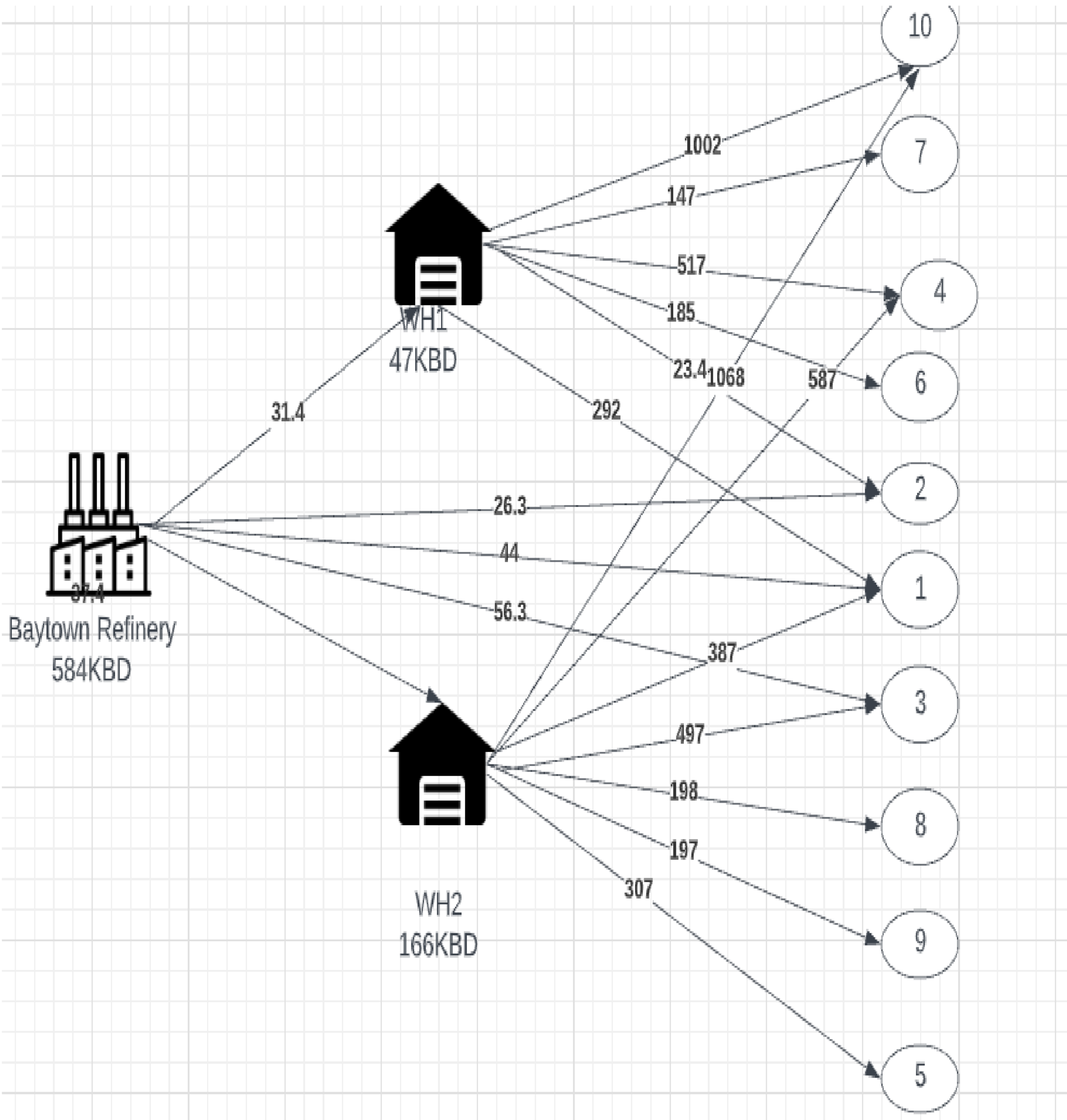


Figure 17 current company flow of products/ Miles Source [own]

Let $J = \{1, 2, 3, \}$ is sites of warehouses and $I = \{1, 2, 3, 4,4,5,6,7,8,9, 10\}$ is a set of ten customers. There is an open cost fj for establishing a warehouse at site $j \in J$. And transportation cost $cij\ of\ warehouse\ j\ serving\ client\ i$.

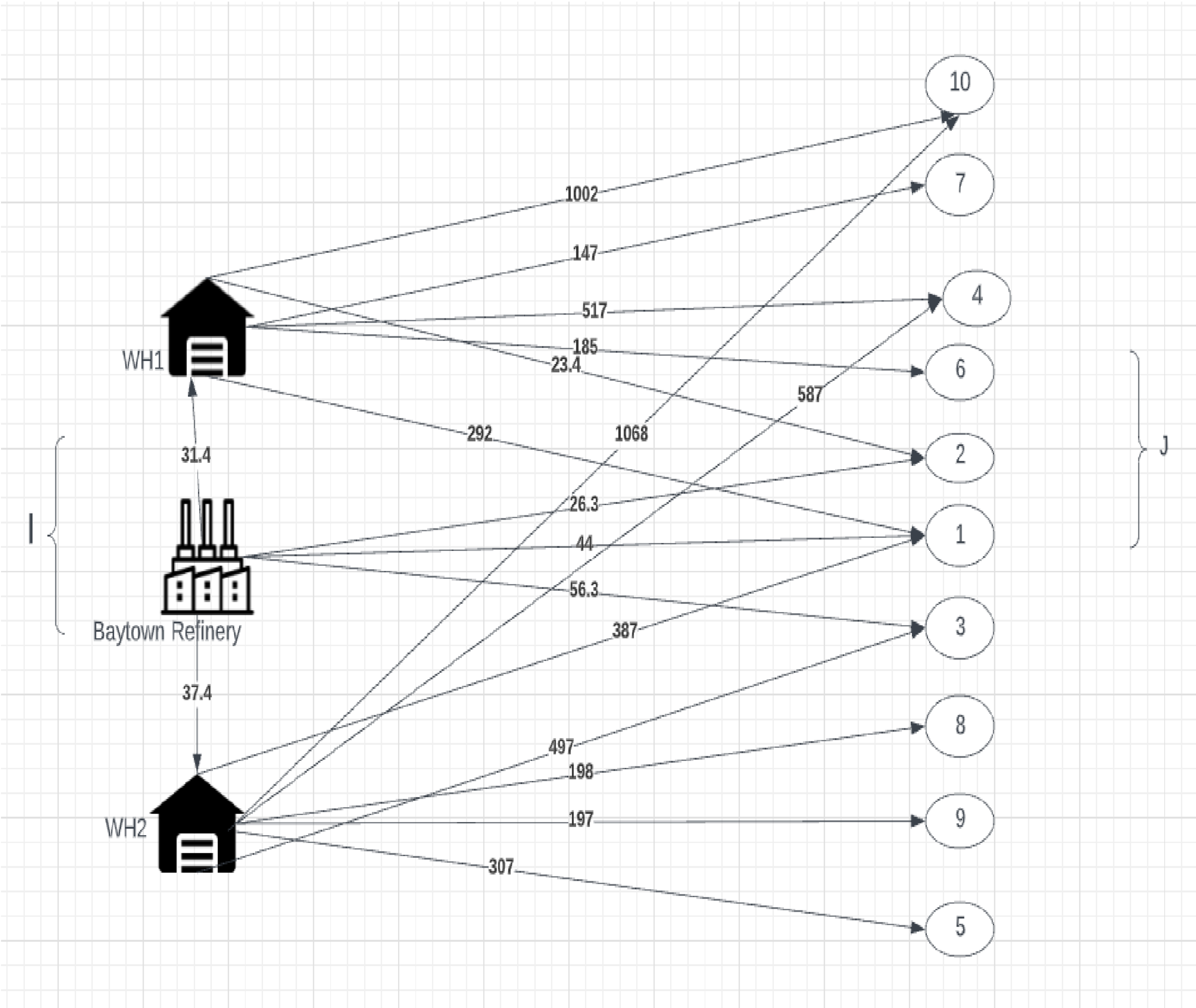


Figure 18 products/ Miles Source [own]

Assigning customers to the closest location of open distributor centers to which has the optimal connection cost. The main objective is to decide the number of warehouses that should be open in their location, this will minimize total cost.

Format Painter

Clipboard Font Alignment

D25

	A	B	C	D	E	F
1	From	To	Distance	Go	Node	Constraints
2	P1	1	44	0	P1	1
3	P1	2	26.3	0	WH1	0
4	P1	3	56.3	0	HW2	0
5	P1	WH1	31.4	1	1	0
6	P1	WH2	37.4	0	2	0
7	WH1	2	23.4	0	3	0
8	WH1	10	1002	1	4	0
9	WH1	4	517	0	5	0
10	WH1	6	185	0	6	0
11	WH1	1	292	0	7	0
12	WH1	7	147	0	8	0
13	WH2	1	387	0	9	0
14	WH2	5	307	0	10	-1
15	WH2	8	198	0		
16	WH2	9	197	0		
17	WH2	3	497	0		
18	WH2	10	1068	0		
19	WH2	5	587	0		
20						

Table 5 Miles travel from orgin of product to customer

Sum of Distance	Column Labels												
Row Labels	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**WH 1**	**WH 2**	**Grand Total**
P1	44	26.3	56.3								31.4	37.4	195.4
WH1	292	23.4		517		185	147			1002			2166.4
WH2	387		497		894			198	197	1068			3241
Grand Total	**723**	**49.7**	**553.3**	**517**	**894**	**185**	**147**	**198**	**197**	**2070**	**31.4**	**37.4**	**5602.8**

Table 6 Miles from origin to each customers

Row Labels	Sum of Distance
P1	195.4
WH1	2166.4
WH2	3241
Grand Total	**5602.8**

Table 7 Total traveling miles

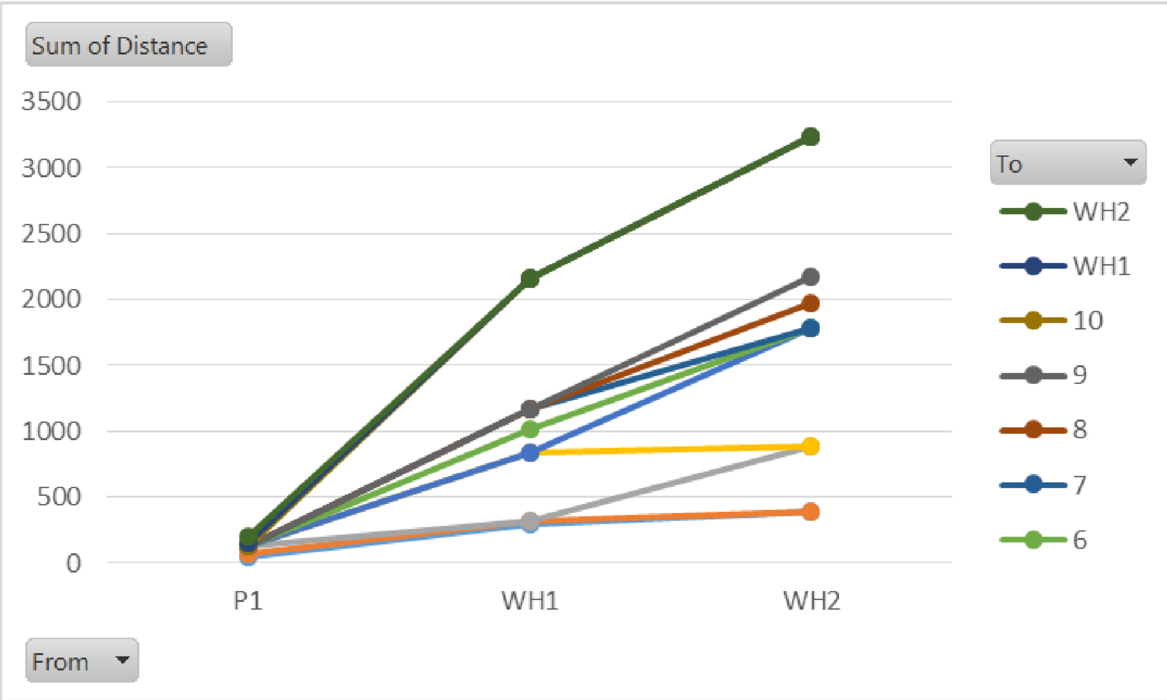


Figure 19 tarvling miles Source [own]

From	To	Distance	Go	Node	Constraints		
P1	1	44	0	P1	1	=	1
P1	2	26.3	0	WH1	0	=	0
P1	3	56.3	0	HW2	0	=	0
P1	WH1	31.4	1	1	0	=	0
P1	WH2	37.4	0	2	0	=	0
WH1	2	23.4	0	3	0	=	0
WH1	10	1002	1	4	0	=	0
WH1	4	517	0	5	0	=	0
WH1	6	185	0	6	0	=	0
WH1	1	292	0	7	0	=	0
WH1	7	147	0	8	0	=	0
WH2	1	387	0	9	0	=	0
WH2	5	307	0	10	-1	=	-1
WH2	8	198	0				
WH2	9	197	0				
WH2	3	497	0				
WH2	10	1068	0				
WH2	5	587	0				
objective function			Min	1033.4			

Table 8 Sensitivity Report objective function Minimum miles travel by truck

The objective function optimal distance from the the plant1 to C10 is 1033.4

From the analysis we can observe that the preferred road choices are from P1 to WH1, AND WH1to C10.

Row Labels	Sum of Reduced Mileage
P1 Go	0
WH1 Go	307.9
WH2 Go	1210.5
Grand Total	**1518.4**

Row Labels	Sum of Shadow Price	Sum of Constraint R.H. Side
HW2 Constraints	0	0
P1 Constraints	37.4	1
WH1 Constraints	-1355.5	0
WH2 Constraints	-1181.9	-1
Grand Total	**-2500**	**0**

Table 9 Sum of Constraint R.H. Side

Transportation cost between production sites and distribution

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	WH1	WH2
P1	$1.00	$1.00	$0.76								$1.00	$1.00
WH1	$0.80	$0.80		$1.80		$0.80	$1.80		$1.80	$0.76		
WH2	$0.76		$0.76	$0.80	$1.74			$0.80		$0.80		

Table 10 Transportation cost between production sites and distribution

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	WH1	WH2		Shipped	Capacity
P1	2000	5000	2000								24000	15000		48000	584000
WH1	2683	500		2000		2000	2000			25000				34183	47,000
WH2	7,114		12000	10000	1781			7000	2169	10000				50064	166,600
Recived	11797	5500	14000	12000	1781	2000	2000	7000	2169	35000	24000	15000			
Demand	15000	10000	14000	240000	2,000	5,000	5,000	15000	7,000	45000	47000	166600			
Total cost		117092													

Table 11 Customer zone demand per product

Material flow from production plants to Distribution centers cost

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	WH1	WH2
P1	$1.00	$1.00	$0.76								$1.00	$1.00
WH1	$0.80	$0.80		$1.80		$0.80	$1.80		$1.80	$0.76		
WH2	$0.76		$0.76	$0.80	$1.74			$0.80		$0.80		

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	WH1	WH2		Shipped	Capacity/ day/bba
P1	15000	0	14000	240000	2000	5000	5000	15000	7000	0	0	10000		313000	584000
WH1	0	0	0	0	0	0	0	0	0	0	0	47000		47000	47,000
WH2	0	10000	0	0	0	0	0	0	0	0	47000	109600		166600	166,600
Recive	15000	10000	14000	240000	2000	5000	5000	15000	7000	0	47000	166600			
Demand	15000	10000	14000	240000	2,000	5,000	5,000	15000	7,000	0	47000	166600			
Total cost	35640														

Table 12 Sensitivity analysis

4.6 Forecast Logistics Demand Using Deep Learning Algorithms

Logistics demand forecasting allows businesses to reliably predict demand for products and shipments across the supply chain, even in the face of unforeseen situations. To do so, logistics organizations can use a forecasting model, such as the one developed to predict capacity demand based on a combination of their own historical data. The model should allow for human forecast adjustments to account for new clients or other company changes and improve accuracy.

Freight forward is one of the big issue in logistics services, in this study cost of freight forwarders has been forecasted.

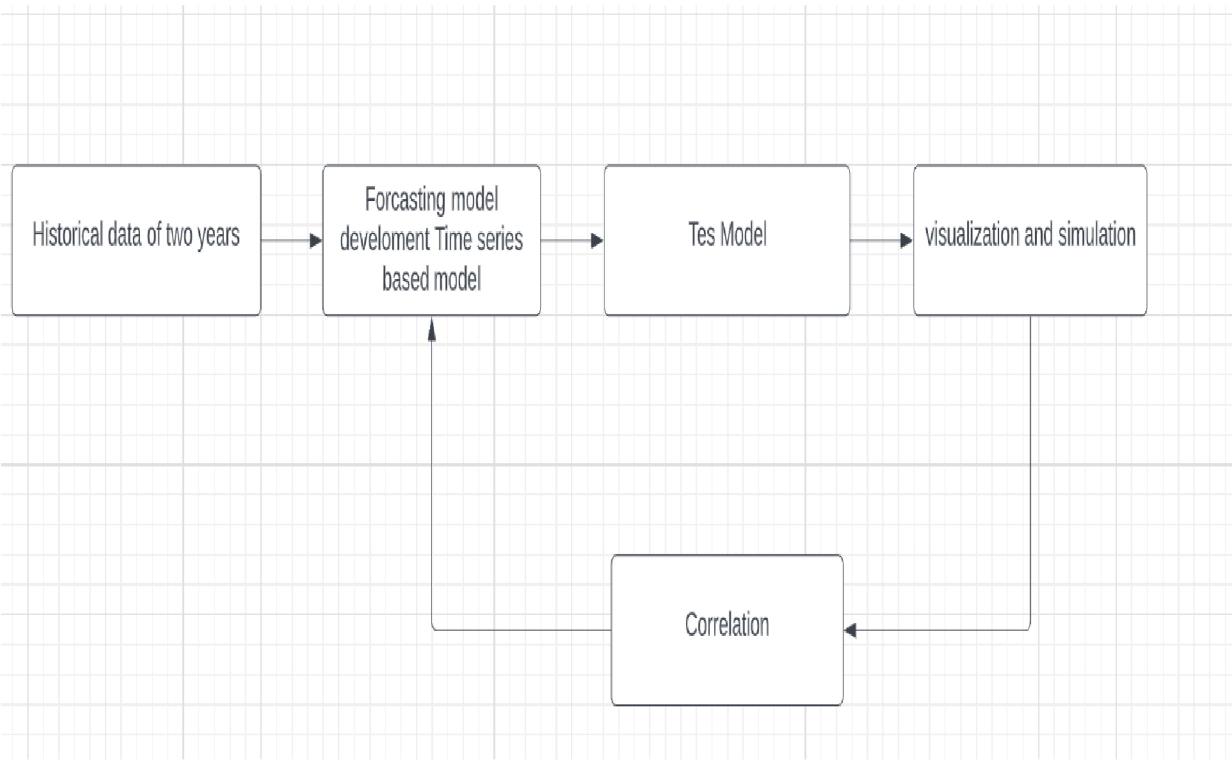


Figure 20 Deep Learning Models for forecasting

4.6.1 Forecasting Freight Cost Using RNN

The forecasting task is implemented on Spyder IDE under Anaconda distribution. Python is used as a programming language by using keras, tensor flow and NumPy.
Simple RNN deep learning algorithm is used to perform the forecasting.

```
model = keras.models.Sequential([keras.layers.SimpleRNN(1, input_shape=[None, 1])])
optimizer = keras.optimizers.Adam(lr=0.005)
```

Figure 21 Figure 20 RNN Model Source [own]

4.6.2 Initial Freight Cost Dataset

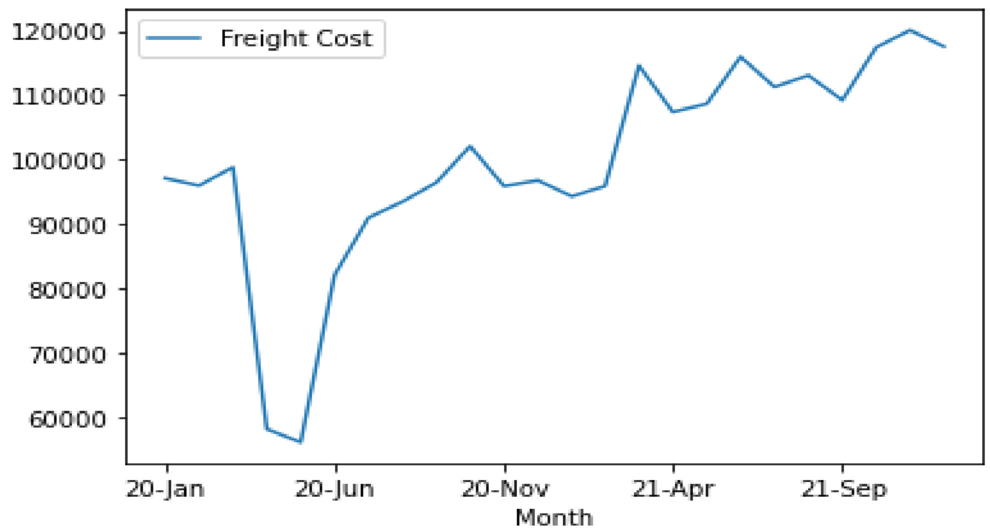
2 years monthly freight cost dataset from January 2020- December 2021 is used to see in the perdition model.

The performed forecasting is a univariate prediction, future freight cost (for timeframe of 7 months) is predicted based on past freight cost dataset.

Freight Cost Dataset

Month	Freight_Cost
20-Jan	97092
20-Feb	95949
20-Mar	98810
20-Apr	58123
20-May	56069
20-Jun	82051
20-Jul	90959
20-Aug	93442
20-Sep	96423
20-Oct	102051
20-Nov	95871
20-Dec	96756
21-Jan	94284
21-Feb	95860
21-Mar	114587
21-Apr	107369
21-May	108646
21-Jun	115955
21-Jul	111270
21-Aug	113075
21-Sep	109220
21-Oct	117417
21-Nov	120094
21-Dec	117548

Figure 22 historical data



4.6.3 Dataset Splitting

Before developing the prediction model, the entire dataset for freight cost divided into three parts training dataset, testing dataset and validation dataset as shown below.

• Training dataset: 10 months of the dataset used to train the neural network model.

• Testing dataset: 7 months of data is used for testing the developed neural network model.

• Validation dataset: 5 months of data used as a validation dataset to validate the training time model.

```
x_train= x[0:11:, 0:2]
y_train= y[0:11:, 0:2]

x_val=x[11:16:, 0:2]
y_val=y[11:16:, 0:2]


x_test= x[16:24:, 0:2]
y_test= y[16:24:, 0:2]
```

Figure 23 Figure 22 Dataset Splitting Source [own]

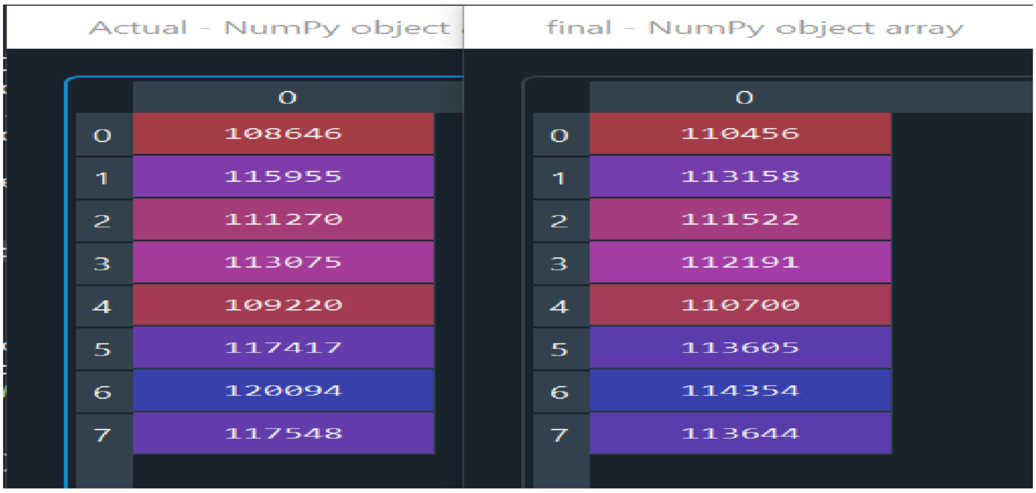
As Supervised learning is performed the dataset has structure of input(X) train, output(Y) train,input(X) test,output(Y) test, input(X) validate, output(Y) validate.

Where X is input

Y is the label for the supervision.

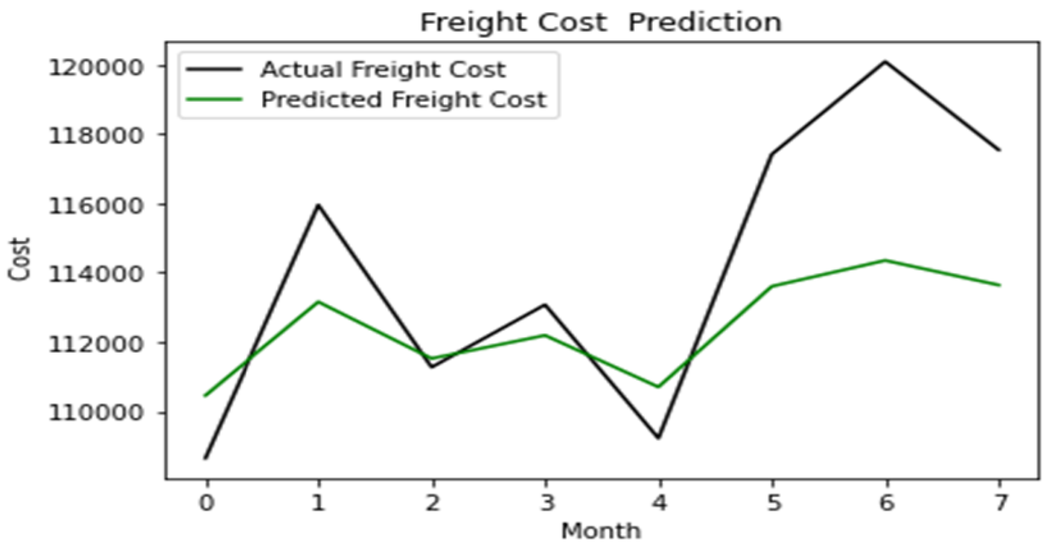
4.6.4 Actual Vs Predicted Freight Cost

7-month actual vs predicted freight cost. As clearly shown the following graph the black line indicates the actual cost and the green one is for the forecasted cost.



	Actual - NumPy object	final - NumPy object array
	0	0
0	108646	110456
1	115955	113158
2	111270	111522
3	113075	112191
4	109220	110700
5	117417	113605
6	120094	114354
7	117548	113644

Figure 24 Actual Vs predicted freight cost Source [own]



Companies can more readily accomplish an accurate forecast in a variety of ways by building and applying their own specialized demand forecasting models. These models can assist businesses in determining how much safety stock they require, as well as how much extra capacity they need to facilitate in order to meet unforeseen demand. Additionally, adopting logistics demand forecasting models can help asset owners such as shipping lines, trucking companies, and intermodal companies reduce the number of kilometers spent repositioning assets, boost cargo vehicle capacity utilization, and increase asset utilization.

In general, a corporation can model two types of logistics demand forecasting: medium and long-term forecasts and short-term predictions. Strategic projections are those that are made in the medium to long term. Companies often utilize this data for budgeting and planning the purchase of new assets such as trucks/ships, warehouses, distribution centers, and the construction of new hub facilities in this scenario. Demand estimates might be ranging from six months to three years in length.

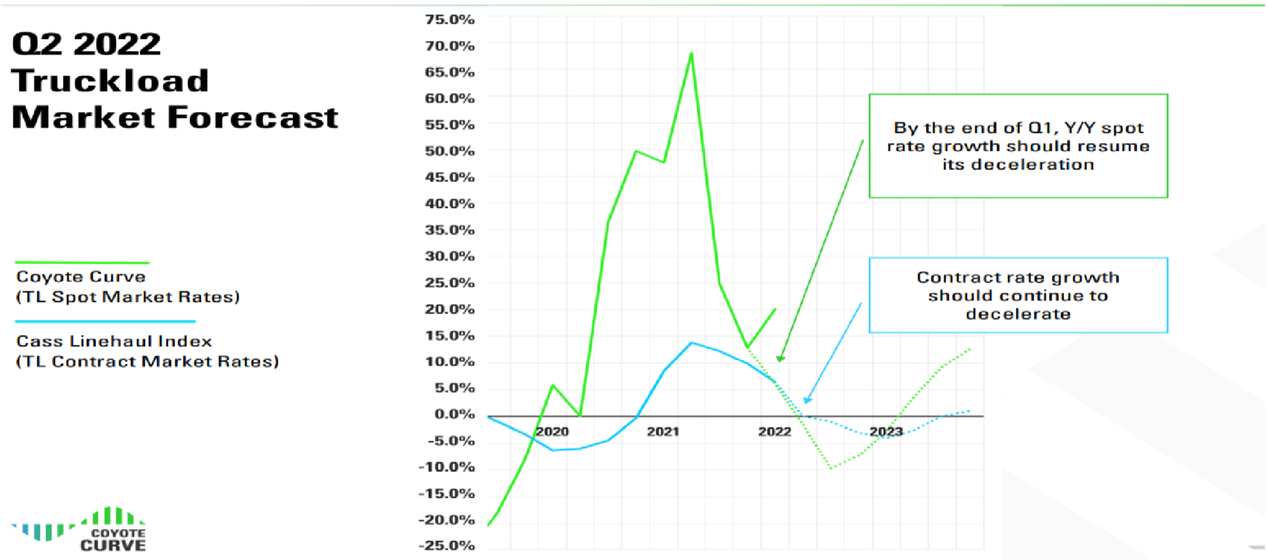


Figure 25 Market forcasting source mordor intelligence

In the above dashboard we can see that the truck market has been forecasted by Mordor intelligence.

4.6.5 Supply & Demand Function in the Truckload Market

Let's take a closer look at how supply and demand work in the truckload market now that you've grasped the fundamentals of economics. The overall quantity of available carrier capacity (trucks and drivers) is referred to as supply, whereas the total amount of truckload volume (loads) from shippers is referred to as demand. This is how a supply and demand curve applied to truckload market dynamics should be viewed. You can see how the equilibrium price point (current spot rates) shifts to meet the trend if either line moves to the left (a decrease) or right (an increase). Because the truckload market in the United States is big and fragmented, and there is no accurate database that tracks the exact amount of carrier capacity at any given time, we must be resourceful in measuring supply. Why is the price of diesel (also known as gasoline) so crucial? Every trucking company's business revolves around fuel. It accounts for 30% of a carrier's total operating costs, and this is true for both owner-operators and national fleets. Fuel prices are substantially more unpredictable than other operating expenses (such as driver compensation) and can change dramatically throughout the year. This volatility has the potential to have a significant influence on carriers' profitability. Carriers are unable to recoup all of their fuel expenditures when diesel prices rise faster than spot rates.

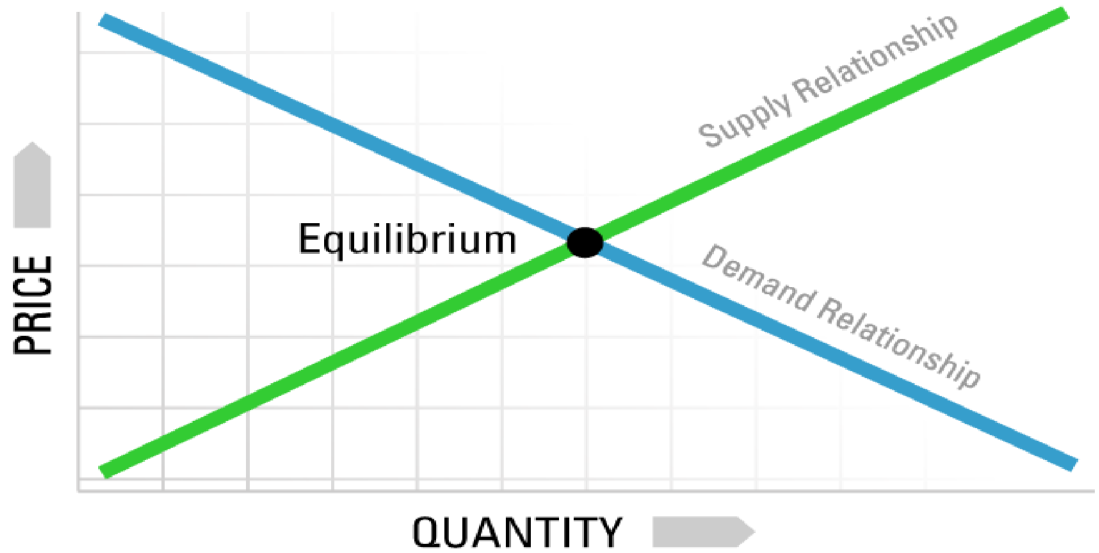


Figure 26 Supply & Demand Function in the Truckload Market

5 Results and Discussion

The results show that optimizing against heuristic decisions that dictate part of the network layout saves money. The savings are significant enough to justify redesigning to the design outcomes. The advantages come from a greater utilization of the plants through the selection of appropriate product portfolios, as well as the reduction of outsourced material. Expenses for total transportation and duties are reduced. Infrastructure considerations also save money despite the fact that the plants are multi-purpose, the organization benefits from operating specific plants in a dedicated mode. This decreases product switching and production costs..

5.1 Distribution Centres

The results of MILP analysis, including a comparison of baseline data indices and optimization attempts for both parts carried and transportation cost. It should be highlighted that as a result of the analysis, costs were reduced, and while there is a mixed trend across data, the overall cost of the project was reduced.

The distribution centers that will be built are assumed to have enough capacity to handle the material that will be received and disbursed, and logistics management will not be an issue at this level. A connection between a manufacturing plant and a distribution center must be at least for a total flow of products 526600/bba

Table 10, shows the transportation costs from the plants to the customers and WHs centers. This is the unit transportation cost, which is unaffected by the type of product or the amount transported. The quantity carried to distribution centers is subject to the duties that have been established and shows the transportation expenses from distribution centers to client demand zones. The customer zones are close to the distribution centers and the allocation for the specific problem is fixed, distribution costs can be overlooked. Table 11, shows the demand by product and consumer zone. The amount delivered to consumer demand zones is subject to the duties that have been established.

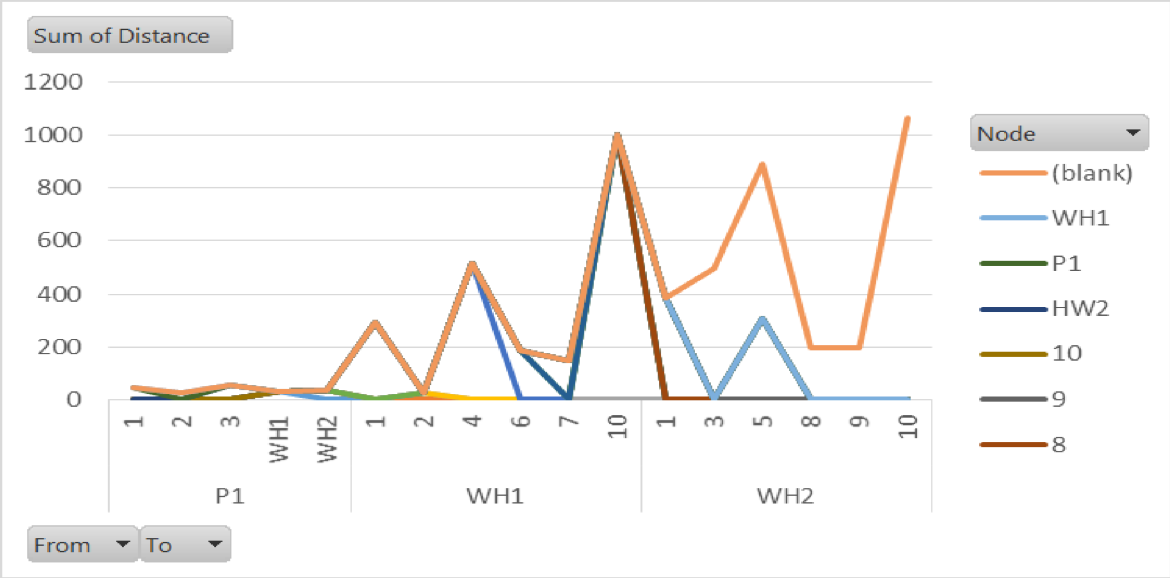


Figure 26 distances travel by trucks *Source [own]*

Sum of Distance	Column Labels		
Row Labels	0	1	Grand Total
P1	164	31.4	195.4
WH1	1164.4	1002	2166.4
WH2	3241		3241
Grand Total	**4569.4**	**1033.4**	**5602.8**

Table 13 Objective fuction

The objective function is a specific path chosen for transportation, the objective function is the sum of the cost of transportation between sites and the number of pieces being transported. The goal function reduces the cost of parts moving through the distribution network. The first and second constraints are to ensure that depots, factories, and warehouses serve as transshipment nodes. The capacity of distribution hubs cannot exceed demand in regions. Similarly, supply and demand are equal.

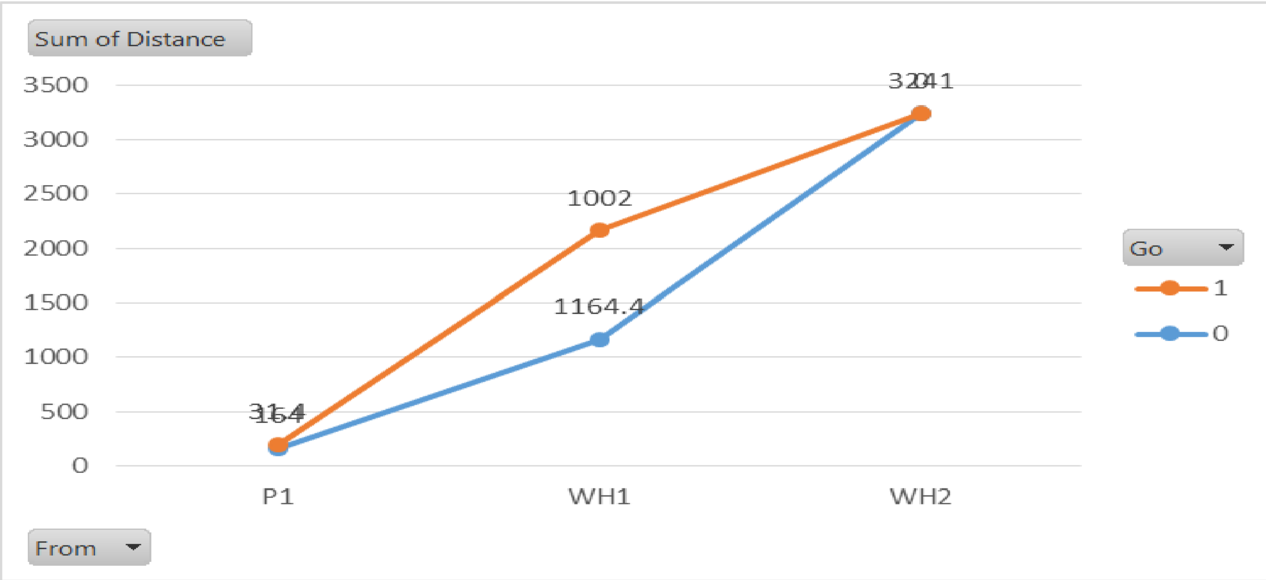


Figure 27 objective fuction Source [own]

5.2 Network Optimization

Optimization exercise in which the model is allowed to make all of the needed decisions, such as product allocation per plant and production level, distribution center establishment and customer allocation, material flows, and distribution center capacity.

The product allocation per facility and the number of days of production per product and outsourced material purchased to meet demand that cannot be met by internal production are shown in the below table.

Row Labels	Sum of WH2	Sum of WH1	Sum of C3	Sum of C4	Sum of C5	Sum of C6	Sum of C7	Sum of C8	Sum of C9	Sum of C10
P1	10000	0	1400 0	24000 0	2000	5000	5000	1500 0	7000	0
WH1	47000	0	0	0	0	0	0	0	0	0
WH2	10960 0	47000	0	0	0	0	0	0	0	0
Grand Total	**16660 0**	**47000**	**1400 0**	**24000 0**	**2000**	**5000**	**5000**	**1500 0**	**7000**	**0**

Table 15 Product allocation per plant and production days allocated

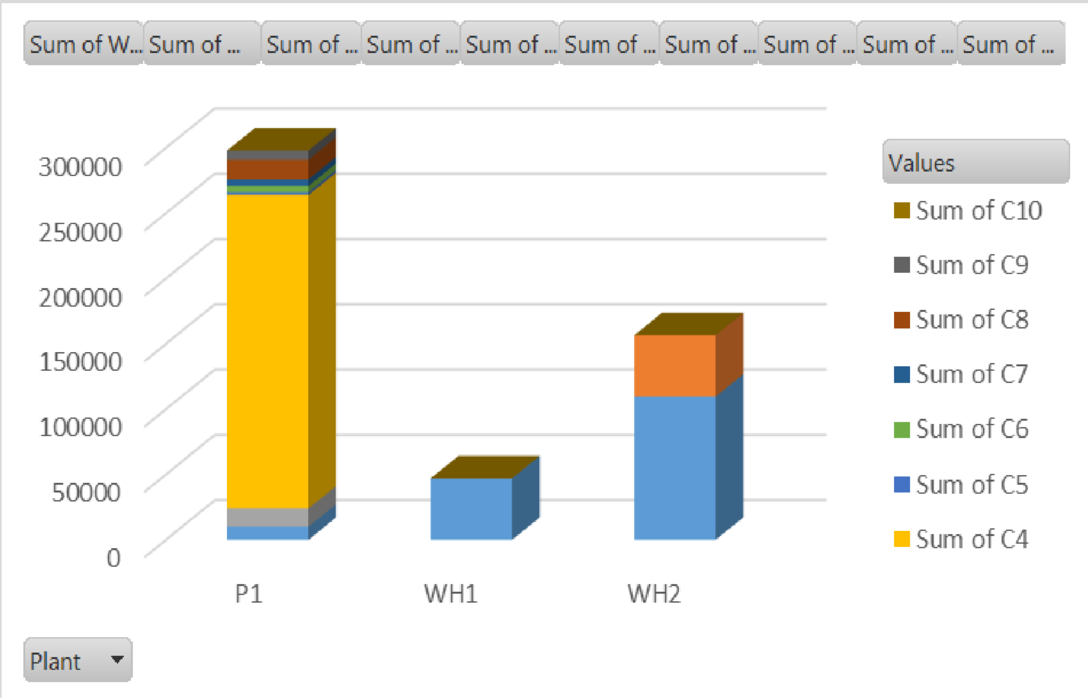


Figure 28 Product allocation per plant Source [own]

Material delivery straight to distribution centers, which then deliver it to the designated customer zones. The below table shows the total amount of material sent from producing plants to distribution centers. This is constrained by the material flow limitation. Total handling capacity 526600/bba.

5.3 Product Allocation and Customer Assignment

Assumes that decisions have already been made on production allocation and network configuration in terms of customer allocation to distribution centers. Product allocation is based on plant capabilities and the plants' bidding process. Second, consumer demands are routed to the closest geographical location available.

The model allows for the optimization of production levels (as measured in days per year and campaigns), network flows, and links between plants and distribution centers. Table 12, displays the levels of activity for each plant based on product pre allocation.

Table 11, shows the material movement between factories and distribution centers.

117092 $ is the total cost of operation in this example.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	WH1	WH2		Shipped	Capacity
P1	2000	5000	2000								24000	15000		48000	584000
WH1	2683	500		2000		2000	2000			25000				34183	47,000
WH2	7,114		12000	10000	1781			7000	2169	10000				50064	166,600
Recived	11797	5500	14000	12000	1781	2000	2000	7000	2169	35000	24000	15000			
Demand	15000	10000	14000	240000	2,000	5,000	5,000	15000	7,000	45000	47000	166600			
Total cost		117092													

Table 11,

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	WH1	WH2			
P1	$1.00	$1.00	$0.76								$1.00	$1.00			
WH1	$0.80	$0.80		$1.80		$0.80	$1.80		$1.80	$0.76					
WH2	$0.76		$0.76	$0.80	$1.74			$0.80		$0.80					
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	WH1	WH2		Shipped	Capacity/ day/bba
P1	15000	0	14000	240000	2000	5000	5000	15000	7000	0	0	10000		313000	584000
WH1	0	0	0	0	0	0	0	0	0	0	0	47000		47000	47,000
WH2	0	10000	0	0	0	0	0	0	0	0	47000	109600		166600	166,600
Recive	15000	10000	14000	240000	2000	5000	5000	15000	7000	0	47000	166600			
Demand	15000	10000	14000	240000	2,000	5,000	5,000	15000	7,000	0	47000	166600			
Total cost		35640													

Table 12, shows the cost breakdown for each individual item. The answer to the problem, as well as customer assignment to distribution centers. These links were made permanent.

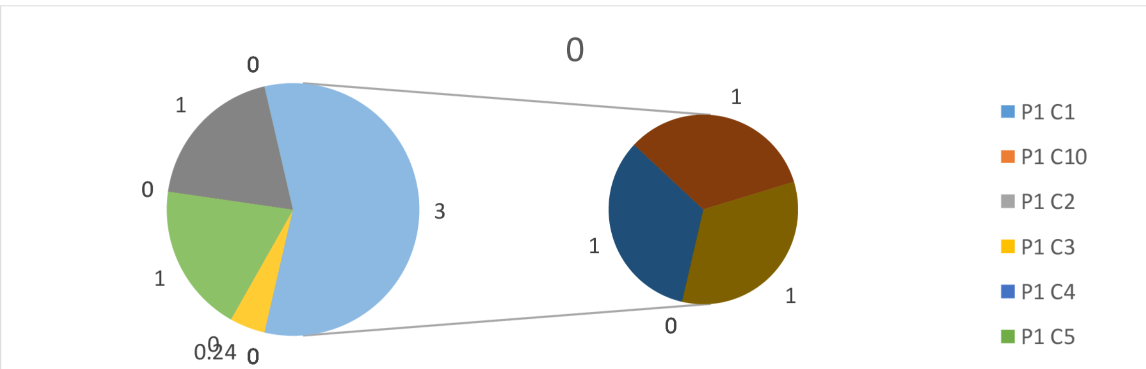
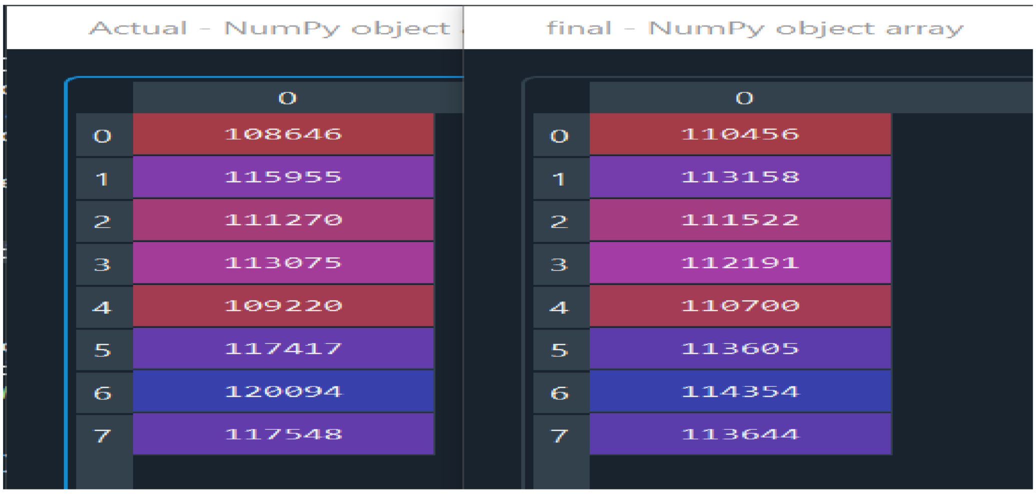


Figure 29 material movement between factories and distribution centers Source [own]

5.4 Forecasting Freight Cost Using RNN

Actual Vs predicted freight cost

7-month actual vs predicted freight cost. As clearly shown the following graph the black line indicates the actual cost and the green one is for the forecasted cost.



Actual - NumPy object

	0
0	108646
1	115955
2	111270
3	113075
4	109220
5	117417
6	120094
7	117548

final - NumPy object array

	0
0	110456
1	113158
2	111522
3	112191
4	110700
5	113605
6	114354
7	113644

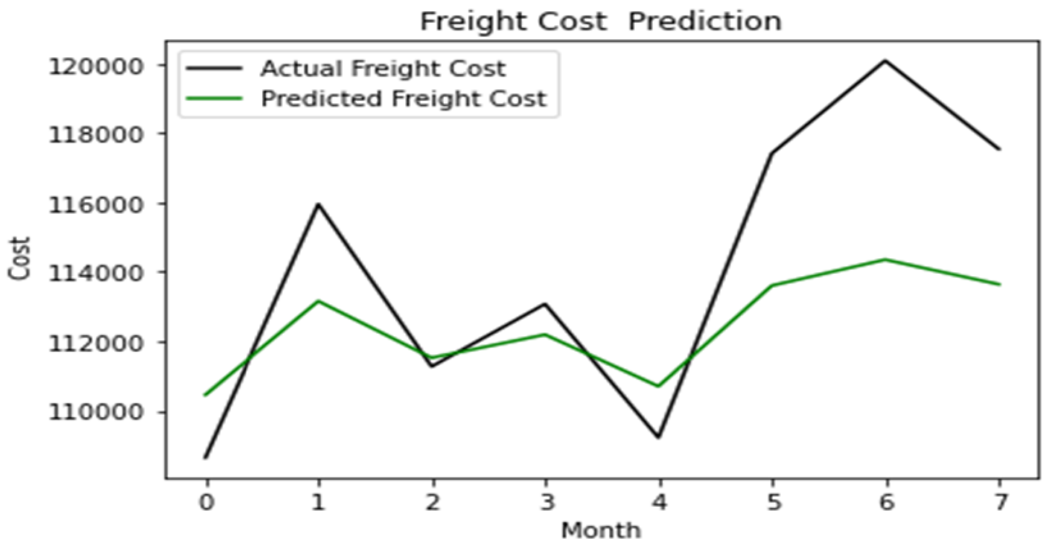


Figure 30Actual cost vs predicted cost Source [own]

6 Conclusion

The integrated model suggested in this research is based on mathematical programs. The network's operating and distribution efficiency, visibility and control of the supply chain, and operational cost, are among the major commercial benefits. Customer happiness and product quality are two important factors. Furthermore, the impact of decisions on the design and development It is possible to quantify and analyze tactical operations because the data is collected through online sources however it can be applicable for any ERP data source, these approaches are simple to use and update each time the application is utilized. The proposed MILP paradigm can be used by any users. In the results of the research there was a decrease in logistics distribution costs consisting of shipping costs and minimizing distance travel by trucks.

Logistics demand forecasting allows businesses to reliably predict demand for products and shipments across the supply chain, even in the face of unforeseen situations. Companies can more readily accomplish an accurate forecast in a variety of ways by building and applying their own specialized demand forecasting models. These models can assist businesses in determining how much safety stock they require, as well as how much extra capacity they need to facilitate in order to meet unforeseen demand.

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8 List of pictures, tables, graphs and abbreviations

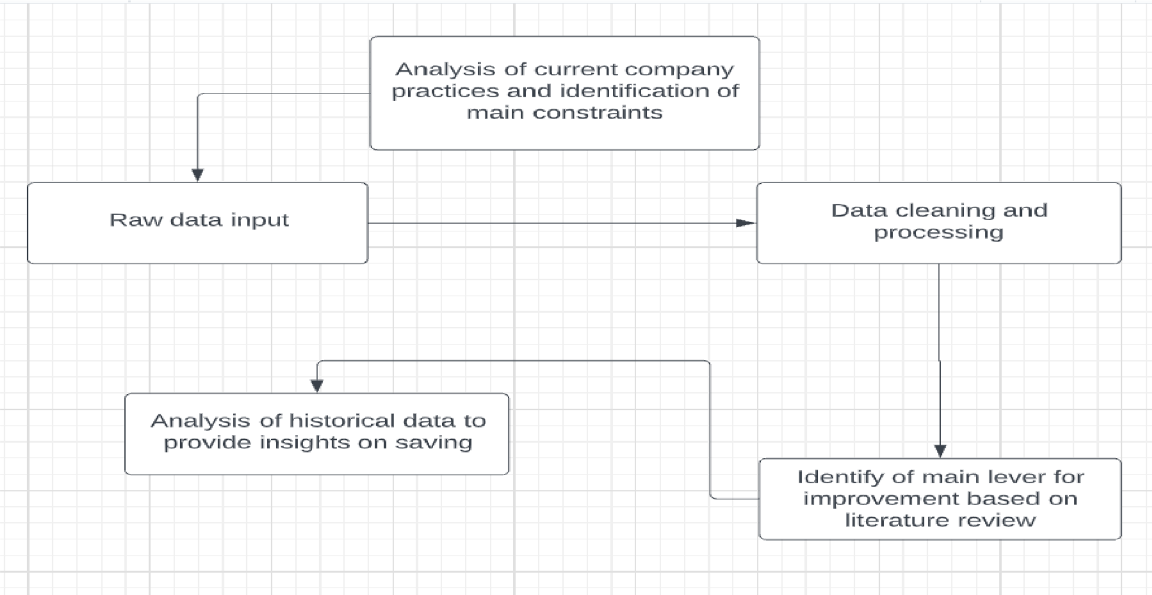

Figure 11Overview of the Proposed System

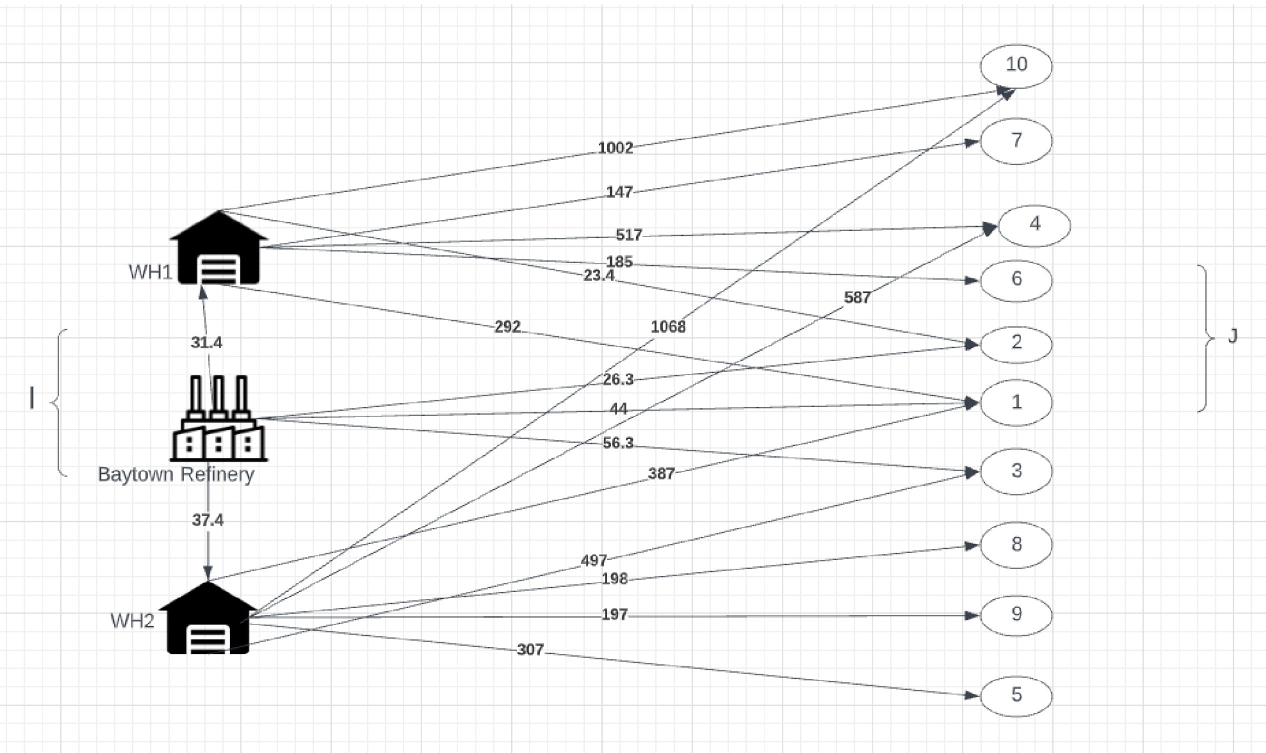

Figure 18, products/ Miles

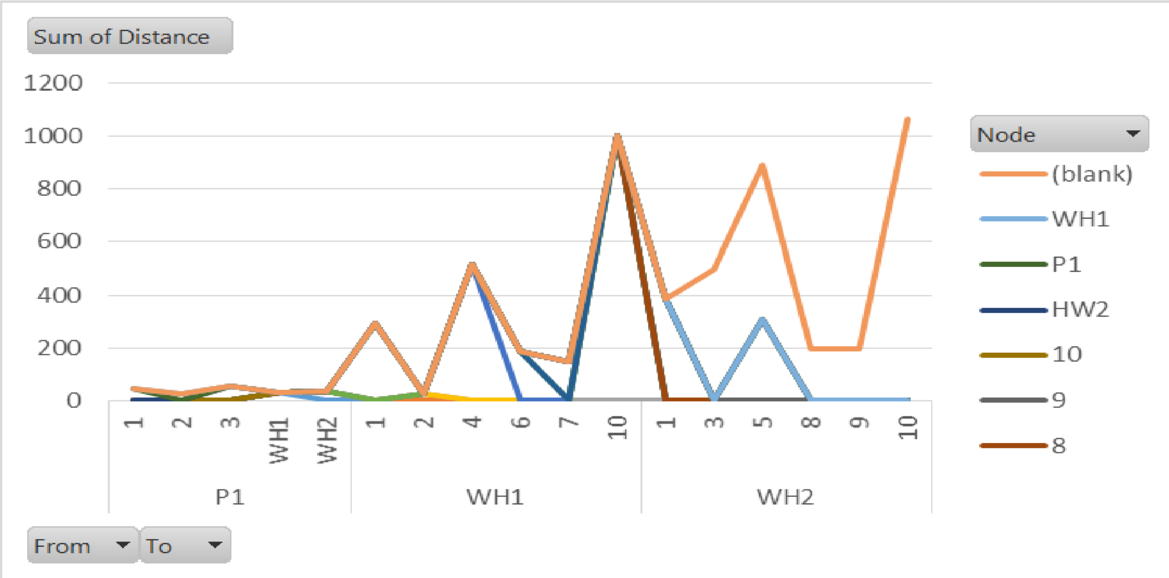

Figure 26 distances travel by trucks

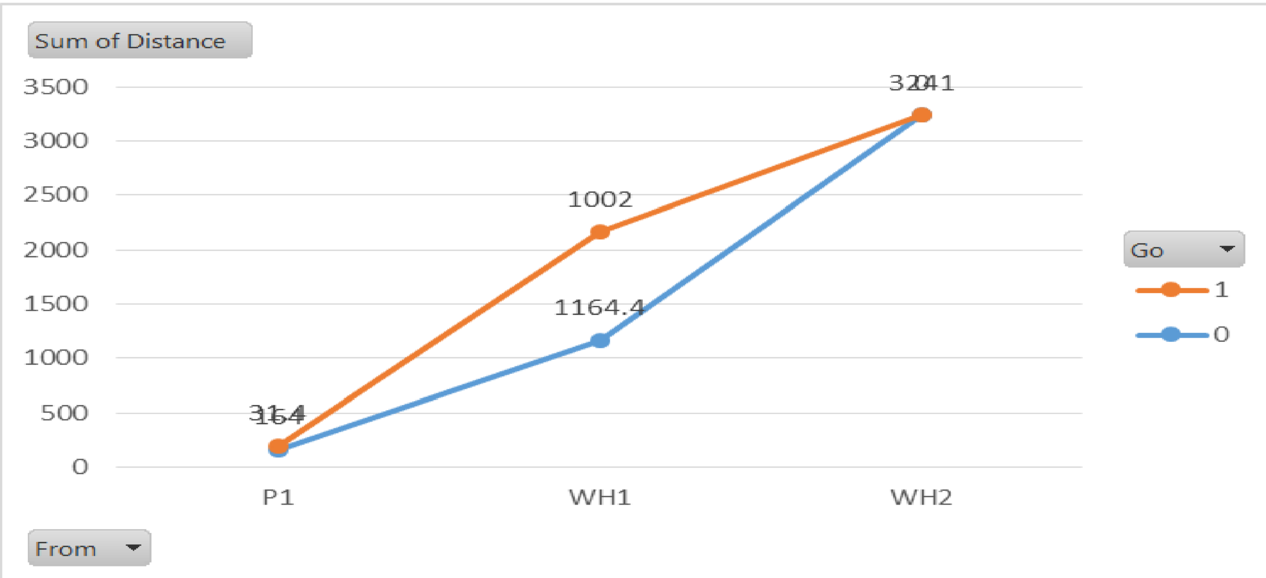

Figure 29 objective fuction

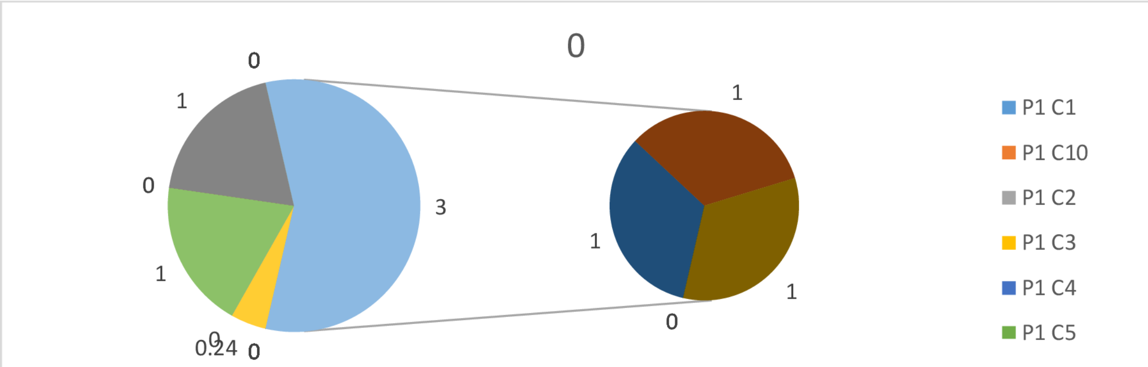

Figure 32 material movement between factories and distribution centers

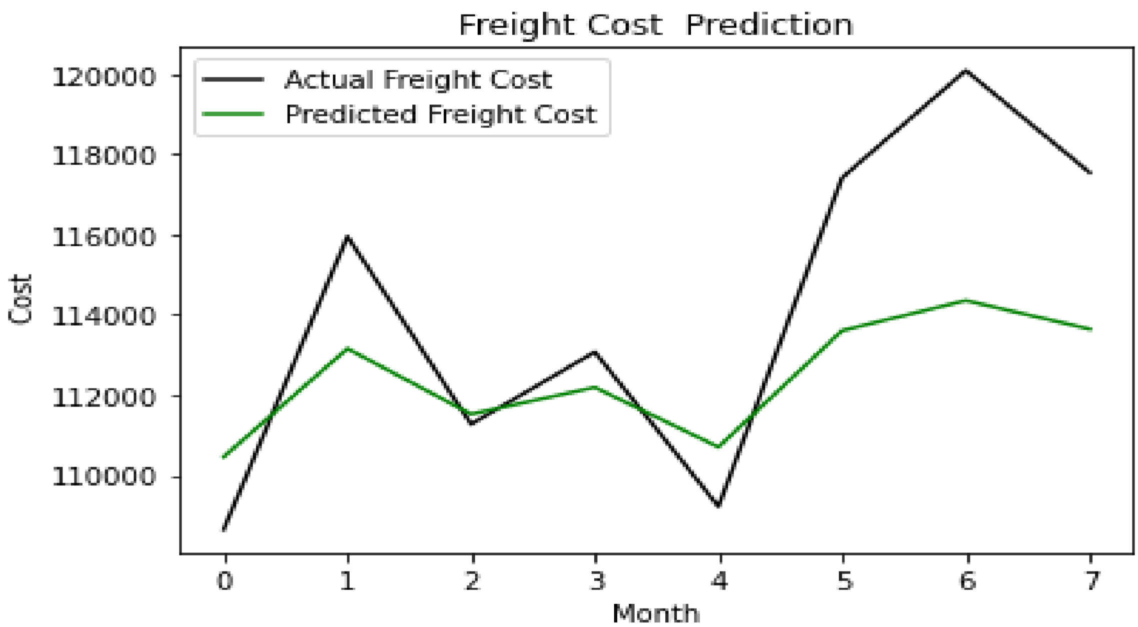

Figure 25 Actual cost vs predicted cost

9 Appendix

Appendix 1

Variable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
D2	P1 Go	0	0	44	279.4	1E+30
D3	P1 Go	0	0	26.3	28.5	1E+30
D4	P1 Go	0	0	56.3	478.1	1E+30
D5	WH1 Go	1	0	31.4	72	28.5
D6	WH2 Go	0	0	37.4	1E+30	72
D7	WH1 Go	0	28.5	23.4	1E+30	28.5
D8	WH1 Go	1	0	1002	72	1E+30
D9	WH1 Go	0	0	517	1E+30	1E+30
D10	WH1 Go	0	0	185	1E+30	1E+30
D11	WH1 Go	0	279.4	292	1E+30	279.4
D12	WH1 Go	0	0	147	1E+30	1E+30
D13	WH2 Go	0	380.4	387	1E+30	380.4
D14	WH2 Go	0	0	307	280	1E+30
D15	WH2 Go	0	0	198	1E+30	1E+30
D16	WH2 Go	0	0	197	1E+30	1E+30
D17	WH2 Go	0	478.1	497	1E+30	478.1
D18	WH2 Go	0	72	1068	1E+30	72
D19	WH2 Go	0	280	587	1E+30	280

Table 6, Sensitivity Report

Appendix 2

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
F2	P1 Constraints	1	37.4	1	1E+30	0
F3	WH1 Constraints	0	6	0	1	0
F4	HW2 Constraints	0	0	0	0	1E+30
F5	WH1 Constraints	0	-6.6	0	0	0
F6	WH2 Constraints	0	11.1	0	0	0
F7	WH1 Constraints	0	-18.9	0	0	0
F8	WH1 Constraints	0	-511	0	0	0
F9	WH1 Constraints	0	-307	0	0	1E+30
F10	WH1 Constraints	0	-179	0	0	0
F11	WH1 Constraints	0	-141	0	0	0
F12	WH1 Constraints	0	-198	0	0	1E+30
F13	WH2 Constraints	0	-197	0	0	1E+30
F14	WH2 Constraints	-1	-996	-1	1	0

Table 7, Sensitivity Report

Appendix 3

Variable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
B10	P1 C1	15000	0	1	0.76	1
C10	P1 C2	0	0	1	1E+30	0
D10	P1 C3	14000	0	0.76	0.24	0.76
E10	P1 C4	240000	0	0	1.8	0
F10	P1 C5	2000	0	0	1	0
G10	P1 C6	5000	0	0	1	0
H10	P1 C7	5000	0	0	1	0
I10	P1 C8	15000	0	0	1	0
J10	P1 C9	7000	0	0	1	0
K10	P1 C10	0	0	0	1E+30	0
L10	P1 WH1	0	0	1	1E+30	0
M10	P1 WH2	10000	0	1	0	0.24
B11	WH1 C1	0	0.8	0.8	1E+30	0.8
C11	WH1 C2	0	0.8	0.8	1E+30	0.8
D11	WH1 C3	0	0.24	0	1E+30	0.24
E11	WH1 C4	0	2.8	1.8	1E+30	2.8
F11	WH1 C5	0	1	0	1E+30	1
G11	WH1 C6	0	1.8	0.8	1E+30	1.8
H11	WH1 C7	0	2.8	1.8	1E+30	2.8
I11	WH1 C8	0	1	0	1E+30	1
J11	WH1 C9	0	2.8	1.8	1E+30	2.8
K11	WH1 C10	0	1.76	0.76	1E+30	1.76
L11	WH1 WH1	0	0	0	1E+30	0
M11	WH1 WH2	47000	0	0	0	1E+30
B12	WH2 C1	0	0.76	0.76	1E+30	0.76
C12	WH2 C2	10000	0	0	0	1
D12	WH2 C3	0	1	0.76	1E+30	1
E12	WH2 C4	0	1.8	0.8	1E+30	1.8
F12	WH2 C5	0	2.74	1.74	1E+30	2.74
G12	WH2 C6	0	1	0	1E+30	1
H12	WH2 C7	0	1	0	1E+30	1
I12	WH2 C8	0	1.8	0.8	1E+30	1.8
J12	WH2 C9	0	1	0	1E+30	1
K12	WH2 C10	0	1.8	0.8	1E+30	1.8
L12	WH2 WH1	47000	0	0	0	1
M12	WH2 WH2	109600	0	0	0.76	0

Figure 33 Microsoft Excel 15.0 Sensitivity Report

Appendix 4

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
B13	Recived C1	15000	1	0	271000	15000
C13	Recived C2	10000	1	0	109600	10000
D13	Recived C3	14000	0.76	0	271000	14000
E13	Recived C4	240000	0	0	271000	240000
F13	Recived C5	2000	0	0	271000	2000
G13	Recived C6	5000	0	0	271000	5000
H13	Recived C7	5000	0	0	271000	5000
I13	Recived C8	15000	0	0	271000	15000
J13	Recived C9	7000	0	0	271000	7000
K13	Recived C10	0	0	0	0	1E+30
L13	Recived WH1	47000	1	0	109600	10000
M13	Recived WH2	166600	1	0	271000	10000
O10	P1 Shipped	313000	0	584000	1E+30	271000
O11	WH1 Shipped	47000	-1	47000	10000	47000
O12	WH2 Shipped	166600	-1	166600	10000	109600

Figure 34Microsoft Excel 15.0 Sensitivity Report