FORMULATING A CONCEPTUAL FRAMEWORK FOR ROUTE PLANNING AND WAREHOUSE DESIGN-OPERATION IN THE E-COMMERCE BASED LOGISTICS COMPANIES IN BANGLADESH.

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CERTIFICATE OF RESEARCH

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*I hereby declare that this thesis entitled "*FORMULATING A CONCEPTUAL FRAMEWORK FOR ROUTE PLANNING AND WAREHOUSE DESIGN-OPERATION IN THE E-COMMERCE BASED LOGISTICS COMPANIES IN BANGLADESH.*" is an authentic report of our study carried out as requirement for the award of degree B.Sc. (Mechanical Engineering) at Islamic University of Technology, Gazipur, Dhaka, under the supervision of Dr. A.R.M. Harunur Rashid, Professor, MPE, IUT in the year 2022*

The matter embodied in this thesis has not been submitted in part or full to any other institute for award of any degree.

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ABSTRACT

Frameworks assist organizations in saving time and increasing the efficiency of their operations by providing a list of all the common process elements found in the majority of businesses that can be used as building blocks. Bangladesh has seen a surge in e-commerce business as a result of the country's growing internet user base, and it is expected that the sector's size will continue to grow over time. Logistics and warehousing are two of the most critical components for this sector's smooth and efficient operation. The purpose of this paper is to develop a conceptual framework for warehouse design, operation, and optimized route map inside four main divisions of the country for the logistics network, of established and new e-commerce businesses. The research employed both quantitative and qualitative methods, with data being gathered from the real-time operation of the logistics system of one of the country's largest logistics companies, as well as from on-site interviews using a structured questionnaire. The research's findings included the proposal of a new warehouse design layout, modern scientific approaches to warehouse operation, and an optimized route map for the logistics system, all of which were implemented using operation research tools in four of the major divisions of Bangladesh. The research as like any other ones is narrowed to some limitations when considered in terms of practical implementation. Space constraints and a lack of modern technologies/skilled manpower may impede businesses from implementing the design and operational strategies of warehouse proposed in the research in a practical setting. The route planning for the logistics system are also always skeptical as the road condition varies a lot in Bangladesh. Moreover, for the sake of simplicity and as an initial proposal, route plans were limited to four divisions and also within those divisions only. This work indeed paves the way for future research to develop a more revised and optimized framework for accomplishing the same goal.

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Nomenclature

AGV	Automated Guided Vehicles
ASRS	Automated Storage and Retrieval Systems
B2B	Business to Business
B2C	Business to Cusomer
CDC	City Distribution Center
CL	City Logistics
COPD	Chronic obstructive pulmonary disease
DC	Distribution Centers
e-commerce	electronic commerce
FIFO	First In First Out
LCD	Liquid Crystal Display
LED	Light Emission Display
LIFO	Last In First Out
LML	Last Mile Logistics
LSCM	Logistics and Supply Chain Management
OR	Operations Research
OW	Own Warehouse
RDC	Retail Distribution Centers
RFID	Radio Frequency Identification
RW	Rented Warehouse
TSP	Travelling Salesman Problem
TW	Time Window
VRP	Vehicle Routing Problem
VRPATW	Access Time Windows for Vehicles
WMS	Warehouse Management System

CHAPTER ONE
INTRODUCTION

1.1. BACKGROUND OF THE STUDY

Bangladesh's business processes have been changed by e-commerce. Bangladesh is the world's most densely populated nation, with around 154.41 million people residing in urban areas and 77 million internet users. Without a question, Bangladesh's economy is rising; it is a developing nation with considerable commercial variety throughout its many regions.

In Bangladesh, the e-commerce business began in the 1990s but failed to expand in the manner anticipated. Economic advancements in areas such as logistics, shipping, warehouse management, communications, and payment methods can create an exceptional potential for e-commerce.

The daily online deliveries for the e-commerce and f-commerce industry in Bangladesh are around 60,000 parcels which is twice that of the traditional courier deliveries done. There are more than 300 delivery companies now in Bangladesh and of those 111 are the members of Courier Services Association of Bangladesh.

Warehouses and distribution hubs of these logistics companies must also adapt to today's extremely competitive and rapidly changing markets. Warehouses must be more adaptable to keep up with changing products and order patterns in order to stay on top of things. It is a facility that receives, stores, and ships the products that have been received. Storage is a key logistics activity that has increased in significance in the architecture of logistics systems over the years, and it is becoming more important. This activity concerns a specialized logistic facility, characterized as a warehouse, but also with different degrees of speciality based on its function and location within the logistics network.

In Bangladesh, the e-commerce sector has outperformed expectations and played a significant role in reshaping the economy in terms of aggregate investment. E-commerce began in Bangladesh in the late 1990s. Between 2000 and 2008, the e-commerce sector experienced slow growth. For the last three years, the annual rate of growth in the ecommerce sector has consistently exceeded 200 percent. In June 2008, the Bangladesh bank reported that credit card payments and transactions totalled nearly Tk11 billion. Significant changes occurred in the aforementioned sector following Bangladesh Bank's approval of online payment in the country, effectively opening the e-commerce sector. For the first time in Bangladesh, the Bangladesh Association of Software and Information Services (BASIS) and the Bangladesh Bank jointly observed "E-Commerce Week" in 2013. B2C commerce is the most prevalent type of e-commerce. For the last three years, it has seen growth rates exceeding 300 percent. B2B and B2C ecommerce market shares are 10% and 90%, respectively. Currently, between 18 and 23% of mobile phone users own a smartphone, a figure that is growing at a 30% annual rate. There are currently 50,000 people employed in e-commerce, with projections of 1,000,000 within the next decade. The average transaction size for ecommerce purchases is still quite small. The average online shopper spends between BDT 9000 and BDT 10000. Around 70.5 percent of e-commerce users make monthly purchases of less than BDT 5,000. About 29.3 percent of buyers make purchases directly through a website, compared to 43.5 percent who make purchases through a

Facebook Page.[1]. The dynamic development of e-commerce and promising future prospects pique the interest of logistic operators in the e-commerce market, particularly in the CEP (courier express parcel) sector. Logistics is frequently cited as a major source of competitive advantage for the e-commerce industry. (Kozerska, 2014; Ambroziak and Tkaczyk, 2015). [2]. The difficulties associated with developing an effective logistics system in Bangladesh are numerous. Though intuitively drawn, one of them is unplanned routing of the logistics system. [3]. E-commerce businesses also tend to require different warehousing than traditional business methods. E-commerce warehouse operations must contend with significant fluctuations in customer order volume and a high rate of product returns. As a result, policies that are optimal for traditional manual warehouses may not be appropriate for e-commerce warehouses. [4]. Conventional warehouses struggle to meet the demands of small orders, diverse assortments, and compressed timelines. [5]. A framework or model for the newcomers or the existing players of the e-commerce sector has not been formed yet which would help to create a more profitable and sustainable business eco-system. The goal of this research is to formulate a framework for e-commerce companies in Bangladesh with a clear and optimised direction for logistics routing, warehouse designing and operation.

1.2. STATEMENT OF THE PROBLEM

In this thesis, we would like to study different routing methodologies for logistics systems and design and operational methods of warehouses to recommend a framework for the logistics system and warehouse design and operation for e-commerce/ delivery companies in Bangladesh.

1.3. OBJECTIVES OF THE STUDY

1. Studying the existing design and operation mode of a few warehouses of renowned companies in Bangladesh.
2. Finding the existing problems and challenges in logistics systems of delivery companies in Bangladesh.
3. Collecting statistical data on the logistic operation of a renowned delivery company in Bangladesh.
4. Creating an optimised routing plan for each division using Vehicle Routing Problem (or Travelling Salesman Problem) based on the locations where maximum parcels are generated.
5. Finally, formulating a conceptual framework of the logistics system and warehouse design and operation for e-commerce/ delivery companies in Bangladesh

This study would be helpful for supply chain managers of any e-commerce or delivery service companies in Bangladesh to give emphasis on the optimised logistics systems and warehousing perspectives.

1.4. SCOPE OF THE STUDY

As a result of the burgeoning e-commerce industry, logistics and supply chain management (LSCM) have been significantly changed, to the point that we are now overwhelmed by its success in both established and developing nations. Recent developments in e-commerce have also helped to expand the logistics business and stimulate the development of logistics-related technology. Typically, logistics is seen, analysed, and applied as a practical instrument that assists the company and other organizational and technological systems in accomplishing their objectives. A number of approaches, methodological procedures, methods, techniques, and tools have been developed for addressing increasingly complex logistic challenges, that is, for developing rational and optimum practical solutions for managing logistics systems and processes. Warehouse operations are also essential in the development of an effective supply chain management strategy. The warehouse operation is critical because it serves as the hub for connecting the nodes to their individual spokes. In today's environment, it is critical to achieving sustained competitiveness. The warehouse operation is critical to meeting consumer demand, and as such, it must be continually enhanced. Continuous improvement may be achieved in part by being adaptable to the specific needs of each client.

The significance of this article is to discuss the function, relevance, and trends of logistics and warehouse development in contemporary circumstances, as well as to discuss various methods of logistics and warehouse studies and implementation as a framework from the perspective of e-commerce and delivery companies in Bangladesh.

1.5. ASSUMPTIONS AND LIMITATIONS OF THE STUDY

The study assumed the trend in logistic behaviour of deliveries to be consistent throughout the time of the year, however the trend changes during festive periods. The parcel generation is higher during religious and cultural festivals in Bangladesh which adversely affect the warehouse as well. The routing plan of the logistics system was done assuming a single truck delivers all parcels in the entire divisions of Khulna, Rajshahi North and South zone of Chittagong, and similarly others. However, considering the higher parcel generation in the Dhaka division multiple trucks were assumed to deliver parcels in this particular division.

As with the majority of studies, the design of the current study is subject to limitations. The warehouse of the companies that were subjected to this research did not have a well-documented outline of their warehouse design. An approximate layout of the warehouse based on-site visit was taken. The data collected on the warehouse layout were also based on the researchers' own calculations. The data on operational parameters of the warehouse were collected from employees and workers working there based on a structured questionnaire from experts.

The route planning for the logistics system was done based on the top 6 receiving zones where the maximum parcels are generated for delivery. Considering the research to be a guideline for new companies planning to get into the sector, these zones can be an initial thought for them.

An ideal case of the roads was considered, which varies a lot in the actual cases in Bangladesh for the congestion, construction works and other restrictions. The lead time tends to increase in the actual case from the ideal case. These are two major limitations in this study that could be addressed in future research.

CHAPTER TWO
LITERATURE REVIEW

2.1. WAREHOUSE CLASSIFICATION

The architecture of our warehouses and distribution facilities is significantly influenced by the highly competitive and continuously changing markets of today. Our warehouses must be far more adaptable in order to keep up with the constantly changing items and changing order profiles we face. Warehouses are facilities where the operations of receiving, storing, and shipping of items take place, as defined by the American Warehouse Association (the latter, in turn, is subdivided into activities of picking from the storage zone, consolidation for forming the outgoing load units, and loading the vehicles used for the deliveries). Storage is a critical logistics activity that has evolved through time to play an increasingly important role in the management of logistics systems. In this activity, we are concerned with a specific facility of the logistics system that is generally referred to as a warehouse, although there are several different and more specific designations for warehouses depending on their functionality as well as their placement within the logistics system. Warehouses are classified into many categories. As an illustration:

I. Owned warehouse: As a result of various factors such as price discounts for bulk purchases, limited capacity of an owned warehouse in an important market place, higher reordering costs, seasonal products, inflation-induced demand, and so on, retailers and wholesalers are obligated to place an order for the purchase of an item in excess of the owned warehouse capacity in the current competitive business environment. As a result of this circumstance, it becomes necessary to hire extra storage space in order to store the surplus units that were acquired. This extra storage space is often found in a leased warehouse setting. According to market economics, inflation is a large and vital factor in the operation of businesses. As a result, the cost of products and services, as well as other expenses, rise. In order to protect themselves from rising costs during an inflationary period, most organizations choose to maintain a larger inventory, which increases aggregate demand. An extra storage area is required, which may be accommodated via the usage of a leased warehouse. During the last several decades, two-warehouse inventory issues have steadily risen in relevance and caught the attention of scholars all around the globe, and this has continued. For a variety of reasons, including fulfilling seasonal product demand, taking advantage of bulk purchasing discounts, and others, the purchase of commodities in excess of the capacity of owned warehouses has become necessary (OW). [6]

II. Rented warehouse: A leased warehouse (RW) is used to store extra units that exceed the capacity of the company's own storage facility (OW). A continuous release pattern is being used to move the goods from the leased warehouse to the company's own warehouse, with per unit transportation costs being taken into consideration. [7]

III. Public warehouse: When it comes to logistics management and services, a PW can be defined as a platform that manages all raw materials and products that are used by the manufacturing factories throughout the entire industrial park while providing professional and unified services such as purchasing, storage, logistics scheduling, distribution and even material delivery to a single production line of each enterprise. [8]

IV. Central warehouse

V. Peripheral warehouse: The peripheral warehouse fulfills orders for peripherals depending on the server fulfilment centre's need. Through the use of a normal distribution, a lead time compatible with industry experience is created randomly. [9]

VI. Distribution Centre: When a set of items is distributed, a distribution centre is a warehouse or other specialized structure, frequently equipped with refrigeration or air conditioning that is filled with products (goods) that will be re-distributed to retailers, wholesalers, or consumers. A distribution centre, also known as an order processing centre, is an important component of the overall order fulfilment process. In most cases, distribution centres are conceived of as being driven by customer demand. In addition to being known as a warehouse, a distribution centre may also be known as a fulfilment centre, a cross-dock facility, a bulk break centre, or a package handling centre. The name by which the distribution centre is popularly known is derived from the reason for which it was established. For example, a "retail distribution centre" is typically responsible for distributing goods to retail stores, while an "order fulfilment centre" is typically responsible for distributing goods directly to consumers. A cross-dock facility, on the other hand, stores little or no product but is responsible for distributing goods to other destinations.

VII. Distribution centres serve as the cornerstone of a supply network since they enable a single place to store a large number of different items at the same time. Some businesses conduct both retail distribution and direct-to-consumer operations out of a same building, pooling resources such as space, equipment, staff, and inventory as needed to maximize efficiency.

VIII. Automatic warehouse; A fully automated warehouse provides numerous benefits, including increased productivity, improved and increased predictability of quality, advanced consistency of processes, and most importantly to the entrepreneur, decreased dependability on the workforce, resulting in lower human labour costs as well as fewer errors. As a result, automation is becoming more important in the everyday operations of more and more businesses. Automatic assembly processes, automated storage and retrieval systems (ASRS), automated guided vehicles (AGV), and the transportation of weighted cargo or materials throughout factories are among the many benefits of using automation. Online transaction processing systems were previously available in e-Commerce and logistics, and they are now commonplace in manufacturing. When it comes to adopting AGV, entrepreneurs place a strong focus on lowering expenses associated with storage and transportation in order to increase overall profit margins. [10]

IX. Cross-docking warehouse: A cross docking warehouse is essentially similar to the standard mixed warehouse in that it has several loading docks. The most significant distinction is that things move through the warehouse fast and do not accumulate as inventory. According to a widely believed belief, there is a continuum of cross docking that ranges from a pure 0 to a short warehouse time. Cross docking warehouses are distinguished by the fact that the things do not enter inventory records in the warehouse management system, and that all of the unit labelling and packaging processes have already been done before the item is brought into the warehouse. The question of how brief a warehouse time to be in order for the procedure to be referred to be cross docking is irrelevant. Even though items never remain in a cross-docking warehouse for more than 18 to 24 hours, this does not always have to be the case in every situation. In cross docking, the most important characteristic is that the products are never placed away in the storage or order picking shelves. They travel immediately from the incoming dock to the departing dock without stopping. According to the procedures and technologies in place, it is possible to have a cross docking warehouse where things are kept in the warehouse for an extended length of time. [11]

X. Quarantine Warehouse: The three racks at the rear of the warehouse are designated as the "quarantine warehouse." This is the location where the equipment that has not yet been regulated is kept. After unpacking a container, if there is insufficient capacity to do the control immediately, the equipment is stored in the quarantine warehouse for safekeeping. It is the remainder of the racks that hold equipment that has been regulated and verified and is ready to be picked up for transmission that is referred to as the main warehouse/main storage. The majority of the equipment is leased out to individual projects from the warehouse, while minor components and consumables are sold directly to the projects themselves via the warehouse. As a result, it is essential to empty arriving containers in order to prevent the rental of returning equipment from being charged to the projects. [12]

2.2. WAREHOUSE DESIGN

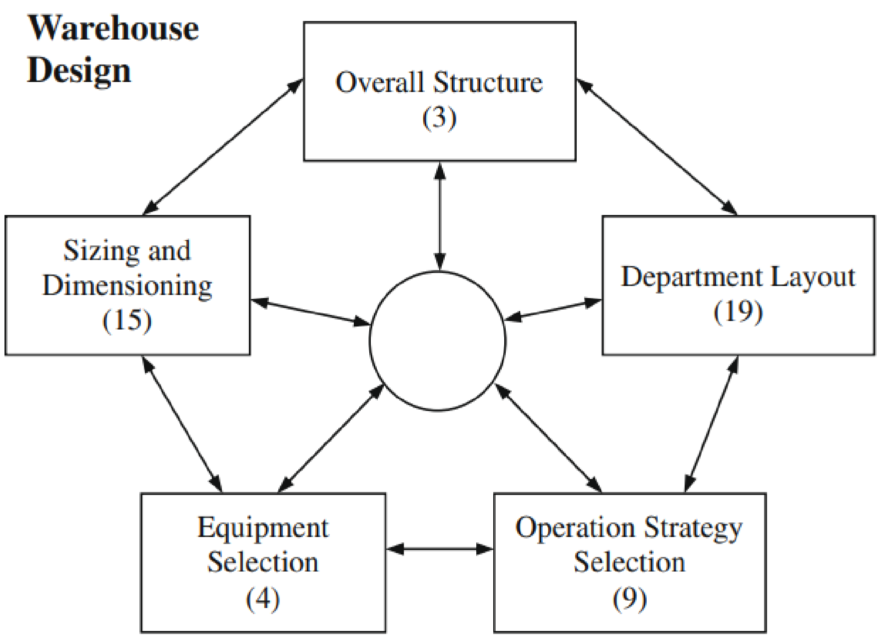

Figure 1: Warehouse Design Problem and Publication Frequency

Warehouse design involves five major decisions as illustrated in figure 1, determining the overall warehouse structure; sizing and dimensioning the warehouse and its departments; determining the detailed layout within each department; selecting warehouse equipment, and selecting operational strategies. [13][14]

The overall structure (or conceptual design) determines the material flow pattern within the warehouse, the specification of functional departments, and the flow relationships between departments. The sizing and dimensioning decisions determine the size and dimension of the warehouse as well as the space allocation among various warehouse departments. Department layout is the detailed configuration within a warehouse department, for example, aisle configuration in the retrieval area, pallet block-stacking pattern in the reserve storage area, and configuration of an Automated Storage/Retrieval System (AS/RS). The equipment selection decisions determine an appropriate automation level for the warehouse and identify equipment types for storage, transportation, order picking, and sorting. The selection of the operation strategy determines how the warehouse will be operated, for example, with regards to storage and order picking. Operation strategies refer to those decisions about operations that have global effects on other design decisions and therefore need to be considered in the design phase. Examples of such operation strategies include the choice between randomized storage or dedicated storage, whether or not to do zone picking and the choice between sort-while-pick or sort-after-pick.

2.3. TYPES OF WAREHOUSE OPERATIONS

Raw materials storage: This kind of warehouse stores raw materials and components either near where they are extracted from the earth or close to where they are processed into finished goods. It is necessary to have raw materials on hand in order to assure ongoing manufacturing. Plastics, precious metals, sand, aggregates, and other similar materials are examples of such materials.

Intermediate, postponement, customization or sub-assembly facilities: This kind of warehouse stores raw materials and components either near where they are extracted from the earth or close to where they are processed for use in manufacturing. In order to assure continuous manufacturing, raw materials must be kept on hand. Plastics, precious metals, sand, aggregates, and other similar materials are examples of such materials.

The figure 2 shows the operations that usually take place in a warehouse in the perspective of supply chain management.

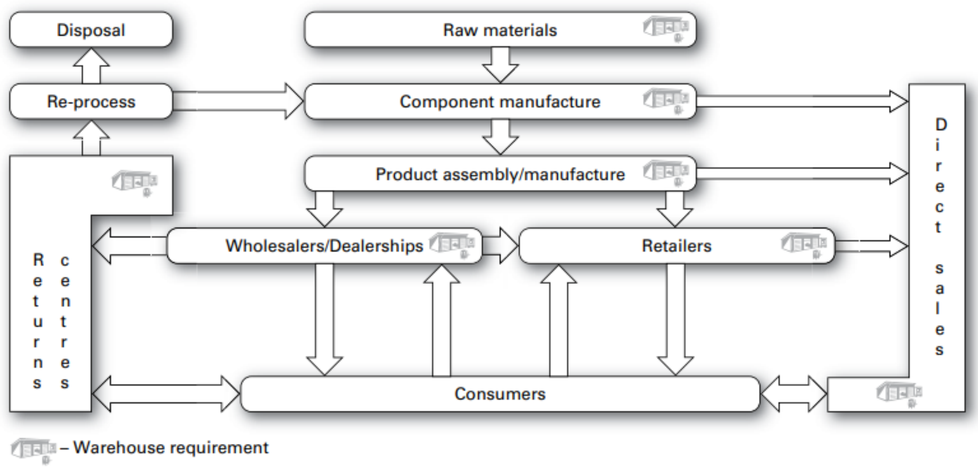

Figure 2: Warehousing Operations in Supply Chain [14]

Postponement and sub-assembly activities can include the following:

I. Particularly specific packaging or labelling being updated or added, for example, for store-ready commodities or printing in many languages;
II. Computer assembly that may comprise a variety of graphics cards, memory chips, software, and other components;
III. Product bundling as part of a promotional campaign;
IV. Items particular to a country, such as electrical plugs, are being added; and
V. Special messages are being added, such as the stencilling of greetings messages on mobile phones, among other things.

Finished goods storage: Manufacturing, wholesalers, and retailers utilize these warehouses to stock items that are ready for sale. These stocks serve as a buffer or safety stock for businesses, allowing them to store up inventory in anticipation of new product launches, anticipated surges in demand, and seasonal fluctuations.

Consolidation centres and transit warehouses: Customers and production lines use consolidation centres to acquire items from a variety of sources and combine them for delivery to the customer or for use on a manufacturing line. This may include just-in-time centres, where automobile components are supplied to a warehouse, where they are gathered together and scheduled for delivery to the manufacturing line before being sent to the customer. They may also serve as retail stock aggregation warehouses, where items from a variety of vendors are gathered and sent to retail locations. Manufacturing facilities instead of delivering part-loads to Retail Distribution Centres (RDC), where their inventory is aggregated with that of other suppliers in preparation for onward delivery to the retail distribution centre (RDC). Unlike cross-dock centres, they are designed to allow merchandise to stay in the centre for an extended length of time while waiting for call-off from the ultimate destination. A large number of these consolidation centres are run by third-party organizations.

Transhipment or break-bulk centres: Transhipments facilities collect huge quantities of items from suppliers and repackage them for onward distribution to different places.

<u>Selection criteria for warehouse location:</u>

- Warehouses are selected based on the following parameters:
- Customer Base
- Supplier Network
- Foreign Trade Zones (FTZs)
- Access to Transportation
- Rental Rates
- Tax Schemes and Incentives
- Workforce Availability

2.4. ORDER PICKING METHODS IN WAREHOUSE

There have been substantial improvements in picking accuracy and productivity thanks to breakthroughs in technology in order picking methods. An adequate return on investment is

Figure 3: Popular Picking Methods in Warehouse

being realized thanks to the usage of barcodes and speech recognition technology in the warehouse. In today's warehouses, paper pick lists, barcode scanning, radio frequency identification, light/pick to light, put to light, and automated picking are all common techniques of picking as shown in figure 3.

The order number, location, product code, description, and quantity are often listed on a paper pick list. Product lines will be shown sequentially in a WMS, allowing the picker to travel the shortest possible route across the warehouse and to their final destination.

Benefits of Pick by Voice

Increased Accuracy
Increased Productivity
Reduction In Paper Usage
Reduction In Errors Through Elimination Of Re-keying Data
Improved Safety Through Hands- And Eyes-free Operation
Reduction In Damage
Real-time Stock Updates Leading To Fast And Accurate Replenishment
Real-time Updates Regarding Potential Shortages
Increased Operator Time On The Warehouse Floor
Reduced Training Times
Multilingual, Accommodating A Diverse Workforce
Easy To Integrate With Other Systems
Potential Reduction In Employee Turnover and
Normally A Quick Roi

Figure 4: Benefits of Order Picking by Voice

Pick by label method uses a sheet of consecutively printed labels to construct a pick list. Each item the picker takes from the shelf and returns to the supervisor's office must be labeled. If discrepancies are found, fresh labels are made if there is enough stock elsewhere. The pre-affixed address labels save time in the dispatch area. This approach is more exact than paper picking in determining if a mistake was committed in terms of amount. Order picking and other procedures like cycle counting, put away and replenishment are becoming more commonplace with the usage of speech technology in warehouses throughout the world. Many firms are shunning barcode scanning in favor of voice-activated picking as they have the benefits mentioned in figure 4.

Next on, Barcode scanning. A barcode is a series of vertical bars of variable widths that represent letters, numbers, and other symbols. Barcodes can track serial and batch numbers, as well as product and warehouse location data. Despite the lack of standards in logistics, barcodes are not consistent. This might impede the flow of goods and services between businesses and countries.

RFID is a way to identify a specific object with radio waves. It might not be necessary for data to move between tags and readers if they can see each other, but it might be necessary. Toll passes, library books and access ID cards are some of the most common things people use these days. Until recently, it was only used a few times in the supply chain. There has been a rise in public awareness because of programs in the US military, Asda, Walmart, and Tesco that are well-known.[15]

Pick to light and pick by light systems employ light indicators, LEDs, and LCD modules attached to shelves, flow racks, pallet racks, and other storage areas.

This strategy is often used in conjunction with zone selection. An operator scans the barcode on the pick tote or shipping carton as soon as it arrives, indicating which order number is next to be selected. An indication that a decision has been made can be conveyed to the system in this way. Next, the operator's zone receives a notice, and all of the pick places associated with that order are lighted simultaneously.

Put to light method is very common in retail shop restocking operations to make use of this method.

The WMS will combine all of the orders from a certain set of stores into a single order. This might be done based on geographic location or the frequency with which shipments leave the distribution centre (DC). The system must guarantee that the volume of each set of stores is as close as practicable.

The following graph shows the relationship between order picking worker productivity rates and various order picking technologies. In order to better reflect my experience dealing with firms, I altered the graphic below. Using the chart, it is possible to compare the productivity rates that may be achieved with various order picking technologies.

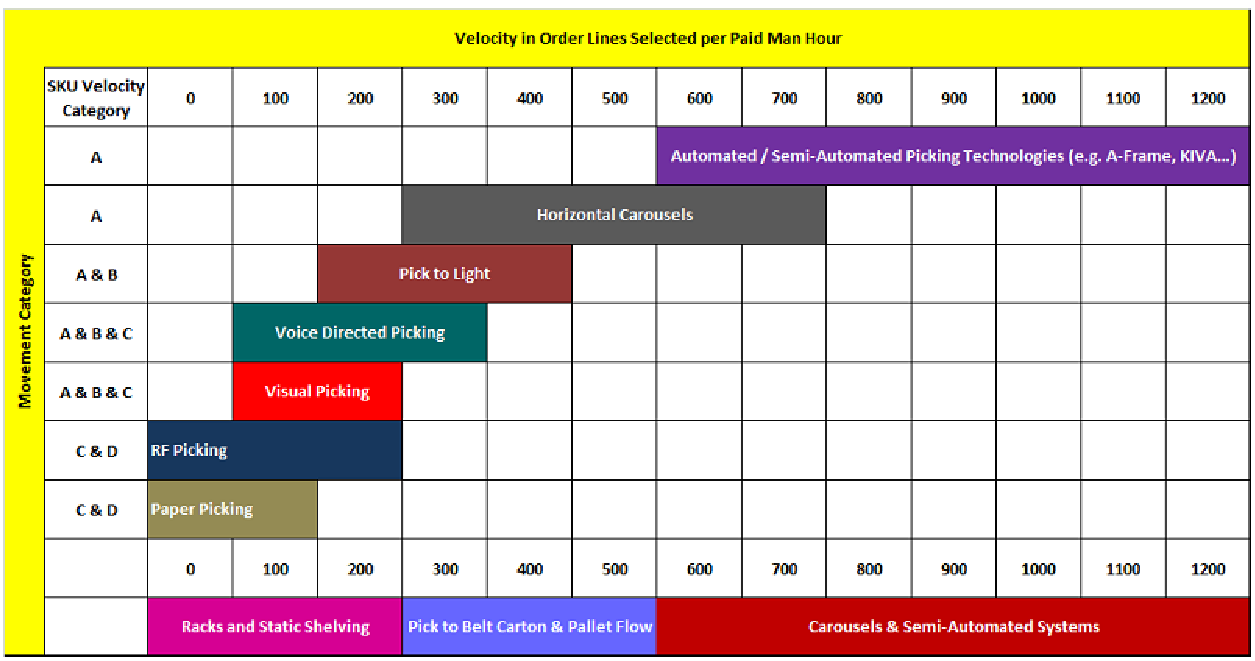

Figure 5: Relationship between order picking worker productivity rates and various order picking technologies

Warehouse managers face a difficult conundrum today, as they are under pressure to decrease costs while simultaneously increasing accuracy, productivity, and service standards.

Before making a final decision, the following points must be considered:

2.5. THE GROWTH OF E-FULFILMENT AND ITS EFFECT ON THE WAREHOUSE

According to Forrester (2013), internet retail sales in the United States will reach $262 billion in 2013, up 13% from $231 billion in 2012, and $370 billion by 2017. Online retail sales in the UK account for around 10% of total sales and are expected to expand between 10% and 15% over the next several years. China's growth rate is closer to 75%. Despite its youth, internet selling shows no signs of slowing down. Goldman Sachs predicts that by 2013, the global e-commerce business would be worth $1 trillion. In terms of storage, pure internet traders have an edge over traditional retailers and manufacturers that sell online, according to a recent TI analysis for Savills (2013). The Warehouse Role 23 must adjust current logistics systems and facilities or build new ones to enable multichannel shopping. The research estimates that specialized e-commerce fulfillment centers need 200,000 orders and warehouses range from 20–60,000 square feet. Operating an e-fulfillment warehouse poses unique problems to warehouse managers. Seasonality has a big influence on these warehouses. The seasonal demand on employees and equipment fluctuates greatly: huge bulky things like grills and outdoor furniture in the spring and summer, and smaller electrical items around Christmas. It also affects handling and storage equipment. Second, warehouse managers must effectively handle low-value, single-item orders. This is a major issue for today's warehouses, especially those handling online purchases. In order to choose and pack low-cost commodities, the same amount of labor and equipment is used, but the margin is different. Third, when consumers assert their market power, accuracy and timely delivery become critical to retaining client loyalty. The warehouse manager must also handle inventory. The rise in product lines will put strain on pick sites, while slow-moving and outmoded lines might take up valuable warehouse space. Picking alternatives to ground-floor pick sites such as mezzanine floors, flow racking, and carousels will be required due to the expansion of product lines. Stock turnover must be effectively managed and non-moving stock disposition choices made rapidly in order to free up valuable warehouse space. As previously stated, e-commerce has a high return rate. This may be 30-40% of external volume. Notably, many of the returns are solid merchandise that may be resold but must be thoroughly inspected. Smaller firms will do fulfillment in-store until the volume becomes unmanageable. Many small logistics and postal fulfillment companies now provide e-fulfillment in general warehouses used for other purposes. Once online sales volume became sufficiently, several multichannel businesses built specialized e-fulfillment centers. Others have kept e-retail and conventional shop volumes combined, either to exploit surplus capacity or because splitting channels offers little benefit. There are three kinds of fulfillment centers:

I. Integrated fulfilment, where online sales are integrated with current retail operations.;
II. Dedicated fulfilment, carried out in a purpose-built facility; and
III. Store fulfilment, plucking internet purchases from the shelves for separate store delivery.

Shutl's same-day courier service has a record delivery time of 13 minutes 57 seconds for an online purchase! The third option has been used in the past for service launch and e-fulfilment, but not for a significant business. This section briefly discusses customs warehousing, refrigerated storage, and fashion logistics.

2.6. PERFORMANCE PARAMETERS OF WAREHOUSE DESIGN

A variety of indicators may be used to evaluate a warehouse's performance.

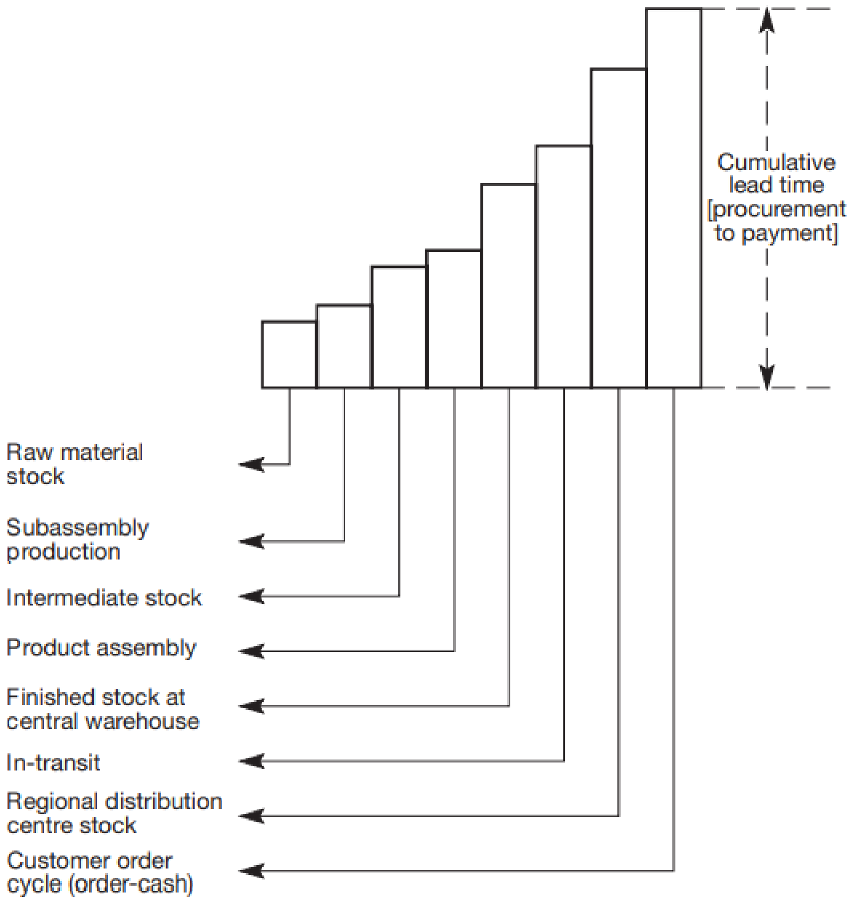

Figure 6: Strategic Lead Time Management

2.6.1. Capacity of Exploitation of the Available Storage Space

To determine the capacity of available storage space to be used, the following space usage characteristics may be used:

I. Surface utilization rate, defined as the ratio of the effective surface area employed to store load units to the total warehouse surface area;
II. The ratio of the volume occupied by stored load units to the overall volume of the warehouse is used to calculate the volume utilization rate.

2.6.2. Warehouse Area Utilization

This may be quantified in a variety of ways. We may examine floor space usage, but a more practical metric is the warehouse's cubic capacity.

Alternatively, we may compare the number of pallet sites used to the total number of pallet locations possible.

The formula is *(Space used X 100) / space available.*

For instance, space utilization is 8,600 occupied pallet spaces minus 10,000 potential pallet spaces or 86 percent usage. If your warehouse is divided into many parts with racking in some and floor storage in others, several calculations will be necessary. Take note that you must determine the amount of space available for storage. Areas utilized for receiving items, dispatching them, and providing value-adding services, for example, should not be included in your estimates. While optimizing space usage is critical for any warehouse, the key to optimizing total warehouse productivity, which includes both space and labor, is to achieve the optimal balance of storage use and handling efficiency.

2.6.3. Potential Capability of the Warehouse of Managing Load Units

The warehouse's potential capacity for managing load units is determined by the following indices:

I. Potential receptivity, expressed as the maximum number of storable load units; this is a static measure of the warehouse's capacity; and
II. Throughput, expressed as the maximum number of load units in transit within a given time unit; this parameter expresses the warehouse's dynamic capacity.

III. Capability of Exploiting Warehouse Capacity

Warehouse efficiency can be assessed by its capability of exploiting its capacity. This can be computed by means of the following parameters:

IV. Potential receptivity saturation coefficient, which is expressed as a percentage of the theoretical potential receptivity that is normally usable during a reference period (daily or monthly), and is defined as the ratio of the average number of load units in the warehouse over the time period considered to the potential receptivity;
V. Selectivity index, represented as the ratio of immediately available load units to potential receptivity during the picking phase. Low selectivity ratings often imply a large number of material-handling procedures required to pick up the departing load units' contents. Therefore, low values indicate the likelihood of providing a lower product flow than warehouses with same physical qualities but a greater selectivity value;
VI. The access index is calculated as the ratio of material-handling activities performed during the reference period (day, month, or year) to the warehouse's potential receptivity. It represents the frequency of material-handling activities. Warehouses with a high access index are consequently extremely dynamic, since the stored items have a shorter warehouse holding period and are therefore handled often; warehouses with a low access index, on the other hand, are more static, with fewer material-handling procedures;
VII. Inventory turnover index, which is determined as the ratio of the value of incoming items to the value of the warehouse's average inventory level during a certain time period. Thus, the inventory turnover index is a non-dimensional number that, when defined in

this manner, represents the degree of mobility of immobile capital (how many times the capital invested in stock rotates in a planning period).

In the case of a yearly time horizon, typical values of the inventory turnover index are between 5 and 10. However, warehouse efficiency may also be achieved with inventory turnover index values that fall outside the given period, depending on the nature of the products housed in the warehouse.

2.6.4. Economic Efficiency of Warehouse

Finally, the following cost indices may be utilized to determine the warehouse's economic efficiency:

I. Receptivity cost, calculated as the ratio of the yearly warehousing cost to the potential receptivity; and
II. Handling cost, calculated as the cost per load unit handled. It is computed by adding all yearly cost items attributable to material-handling operations and dividing them by annual throughput. Direct expenses include, but are not limited to, personnel costs and energy costs associated with material-handling operations, while indirect costs are mostly comprised of equipment maintenance costs directly associated with material-handling operations.

2.7. FUNCTIONS OF E-COMMERCE BASED LOGISTICS

E-commerce expansion has transformed the physical distribution of commodities in our cities. [16]

By defining e-commerce as Internet-based business-to-customer (B2C) transactions [17], we can say that online purchases and customized delivery are the developments having the most influence on urban freight transportation networks. Diversification of delivery routes and an expanding variety of services provided by merchants and logistic operators are causing changes in the patterns of urban freight movement.

Each day, more commodities must be delivered, more locations must be covered, more vehicles must be moved, and the system becomes more complicated. Social and behavioural variables such as demographic developments, globalization of supply chains, and the adoption of new consumer technology amplify these changes [18]. For example, the recent expansion of e-commerce has resulted in a considerable rise in direct-to-consumer deliveries, bolstering the importance of "last-mile" logistics. Customers may choose not just home delivery, but also other delivery sites such as lockers or pick-up stations.

Last-mile logistics (LML) must be framed inside city logistics (CL) [19]. A market economy defines CL as "the process of entirely optimizing private enterprises' logistics and transportation operations in metropolitan regions with the support of sophisticated information technologies" [20]. Transport planning, logistics, and mode adaptation are all included. Cl provides positive externalities for urban economies and sustainable development, but it also has negative externalities that may aggravate with increased demand. This explains why politicians and regional planners are concerned. Currently, practitioners are progressively realizing the benefits of include urban logistics planning in urban planning [21]. By reducing inefficiencies and externalities associated with the last-mile supply chain, CL and new areas like the Physical Internet present fertile ground for projects that address economic, operational, social, and environmental sustainability [22].

Applying the Physical Internet to urban surroundings, for example, creates hyper-connected city logistics, a conceptual framework for constructing much more efficient and sustainable urban logistics and transportation systems [23]. Thus, e-commerce has a number of difficulties. One of them is responding to a rising volume of orders from a variety of different regions. These may be located anywhere from a few meters to a few kilometres apart and have incredibly small time intervals [24]. The delivery size (small) and frequency (high), the network organization (large number of recipients dispersed around the city), and the logistics operations themselves (which are performed by wholesalers, suppliers, and retailers) [25]. All of this needs continuing innovation in cost-effective last-mile delivery technologies [26].

Three types of last-mile innovations exist: organizational, technical, and data-driven. The first category includes the implementation of novel last-mile organization structures or methodologies. Urban consolidation centres [27] [28] [29], synchronization, and horizontal collaboration [5, 40–42] are all examples of this.

Clearly, minimizing the adverse effects of urban freight transportation and optimizing load flow efficiency are critical objectives of CL. However, there are others. The first step in developing a successful urban logistics strategy is to analyse all viable choices for the different stakeholders [30]. Stakeholder performance in crowdsourcing, urban development, and crowd logistics must be improved [31]. Effective logistics strategies and traffic management need an understanding of the interests of the many stakeholders. Collaboration and information sharing between local governments and logistics service providers are undoubtedly beneficial, but an united and long-term vision for urban freight transportation regulations across cities and regions might be transformative [32]. Local governments and logistics corporations will continue to face socioeconomic, operational, and environmental trends and concerns [33]. The literature cites a lack of measurement and assessment methodologies to aid decision makers in comprehending the operations and performance of urban distribution systems. This would allow them to improve policy integration and decrease negative externalities [27].

Indeed, some authors advocate for public officials to act as mediators rather than supervisors [25].

The authors describe e-commerce as an internet-based technology that allows the interchange of product, order, payment, and delivery information to complete a commercial transaction. Parties do not need to engage into legally binding transactions to transfer property rights for the purposes of this study. Individual travel behaviour will be influenced as people use the Internet to seek and compare.

Some studies (e.g. [34] distinguish between three types of e-commerce: business-to-business, consumer-to-consumer, and business-to-consumer (b2c). This essay focuses on B2C e-commerce since it affects both individual travel and freight transportation. Notably, B2B e-commerce promotes web/Internet-based marketplaces for goods and services, including transportation and storage. This latter need may be required to effectively deliver online purchases and hence compete with other stores using the internet or other methods. Consumer-oriented e-commerce include promotion, ordering, shipping, and customer support (Hameed 2003). Contacts may recall a person's interests and requirements, allowing for tailored advertising. It may also be participatory, with users gaining knowledge about their own requirements via immediate response. Then, reference or peer groups may discuss and make observations on their experiences with the on-sale items.

A variety of ordering choices are available, including product databases, payment methods, and delivery methods. The Internet may also be used to purchase and transmit digital things such as software, news, and music, saving time and money

Finally, business-to-consumer e-commerce offers post-purchase assistance through email, search engines, and active discussion forums.

Ecommerce may be conducted through a personal computer, television, or mobile device. Access to the Internet and information exchange in an open network, rather than a closed network comprised of a limited number of persons, is critical for accessibility and mobility (extranet or intranet). As a result, massive numbers of potential buyers and sellers may interact regardless of their geographic location. However, the kind of electronic equipment used in business-to-consumer e-commerce has some limitations.

A value system perspective may assist in comprehending business-to-consumer e-commerce [35]. Value systems are comprised of businesses involved in the production of a certain good (from raw material collection through delivery to the customer). The downstream end of value systems, referred to as “supply chains,” is the subject of this research.

They establish connections between businesses and consumers through information, physical, and financial flows.

Information flows both upstream and downstream. Consumer preferences increasingly direct supply chain operations [36], a process dubbed 'supply-chain reversal' [37].

To improve collective performance via lower supply chain costs and improved service, business-to-consumer e-commerce promotes' supply chain integration' [37].

Supply chain consequences of business-to-consumer ecommerce:

i. Familiarity with the individuals who make up the chain.
ii. Purchase and travel patterns of the general public.
iii. Consumer behaviour and travel patterns are important considerations.
iv. Consumers' preferred places of employment and residence
v. The customer wants to know the amount and kind.
vi. Systems for delivering items requested online, such as logistics and transportation solutions for home delivery and other e-commerce services, are also included.
vii. The geographic patterns of dispersion of different distribution systems are investigated.

2.8. DELIVERY ROUTE OPTIMIZATION

Delivery Route optimization is the practice of continually improving a route linking distant locations. In other words, it comprises identifying the most efficient route between locations A and B and optimizing that route depending on critical characteristics such as traffic congestion, the number of stops, one-way streets, and weather. Delivery route optimization is critical for same-day and one-hour deliveries.

2.9. DELIVERY ROUTE PLANNING

Delivery planning a route is determining the most effective route to take while avoiding crowded traffic congestion. To put it another way, it is identifying the quickest and most cost-effective path between two sites.

Consider the following scenario: you work for a third-party delivery business that serves five local restaurants. You must send several orders with a restricted number of drivers on Saturday, which is a very busy day.

The route planner for delivery services will aid anyone in identifying the most effective routes for all vendor deliveries using the information they provide. [38]

2.10. VEHICLE ROUTING

Two objectives are served by optimizing city transportation routes. The primary objective is to alleviate traffic congestion and promote the mobility of freight transportation services in urban areas. The second objective is to have a positive influence on the environment and sustainable development, particularly by lowering GHG emissions, pollution, and noise, and improving city people's living conditions.

Due to the diversity of stakeholders in metropolitan areas, the objectives differ [39]. Stakes in the public realm are determined by their use to the community. Their aspirations may conflict with individual performance and the business stakeholders' objectives, which include maximizing profits via cost reduction and service quality improvement. Additionally, these two stakeholders have differing degrees of influence over how their objectives are accomplished. Local governments can only influence car flows by enacting specific regulations. Due to the fact that each stakeholder has a unique objective and leverage, the vehicle routing models created for them are rather diverse.

Local authorities

[40] studied restricting access to certain zones at certain times. The problem is a Routing Issue with Access Time Windows for Vehicles (VRPATW). Time windows for access (access TW) are distinct from VRPTW time windows in that they restrict access to the whole area (usually called restricted zone). As a result, they have no effect on delivery times, but rather on vehicle entrance times. Additionally, they do not need customers. [40]demonstrate how such rules raise carrier costs and require carriers to use extra vehicles.

Limited access may be combined with a city distribution centre (CDC) for the purpose of loading commodities onto more environmentally friendly trucks. In this case, limited zones are reserved for certain types of vehicles. [41]detail how such layouts will result in a reduction in truck kilometres in metropolitan areas. [42] model this scenario as a two-echelon VRP and examine how employing CDC may reduce global expenditures.[43][44][42] and [45] have recently examined temporal choices and synchronization problems across a variety of vehicle classes. Additionally, they examine the effect of TW and automobile restrictions on urban product distribution. They compute routes using the conventional VRPTW approach, changing the input to simulate a variety of scenarios.

A critical factor that planners should consider is the strong correlation between the time of day and travel times in urban areas. With the advancement of information technology, a greater volume of data is now accessible for modelling (see, for example, Ehmke and Mattfeld 2010b and Ehmke et al. 2012). Numerous authors, including Taniguchi and Shimamoto (2004), Ando and Taniguchi (2006), Ehmke and Mattfeld (2010), and Kritzinger et al(2012)., follow this line and incorporate time-dependence into their VRP models The results demonstrate how it contributes to CO emission reductions (7 percent, Maden et al. 2010) and time window violations (solutions calculated without taking into account time-dependent travel times result in up to 60 percent of missed time windows when evaluated in a time-dependent context, Donati et al. 2008). Another feature of cities is their dynamic nature. Technical solutions now exist to deal with unanticipated incidents by monitoring the fleet during operational hours and intelligently rerouting cars in response to these situations. Numerous authors have examined how this information can be used to improve route optimization: Zeimpekis and Giaglis (2005), and Qureshi et al (2012). A third challenge that carriers often confront while transporting products in urban areas is the road network layout, particularly in older European cities, where streets are small, lack parking, and are frequently one-way (Crainic et al. 2004; Muuzuri et al. 2012b). Then, due to structural constraints, large trucks cannot easily enter city centers, and small vehicles must be used. Due to their capacity limitations, these smaller trucks make many round journeys during the day. Thus, route optimization differs from traditional VRP, which allows only one trip per vehicle. Fleischmann (1990), Browne et al. (2011), and Delaître and De Barbeyrac(2012) all explored this scenario (in the context of urban logistics). Fleischmann (1990) was the first to consider this issue in the context of miscellaneous goods delivery in Berlin, fresh food delivery in Duisburg, and beverage delivery in Dortmund, demonstrating how it enables more efficient use of the time horizon and vehicle capacity. Vehicle routing problems for city logistic

2.11. TRAVELLING SALESMAN PROBLEM

The Traveling Salesman Problem (TSP) is a well-known example of a classical combinatorial optimization problem that is straightforward to formulate but very complex to solve. The objective is to determine the shortest tour across a collection of N vertices that visits each vertex precisely once. This issue is known to be NP-hard, which means that it cannot be solved in polynomial time. Numerous techniques, both accurate and heuristic, have been developed in the discipline of operations research (OR) to address this issue. The purpose of this article is to offer an overview of the many ways utilized to solve the traveling salesman issue. Numerous heuristic strategies, such as the greedy method, ant algorithms, simulated annealing, tabu search, and genetic algorithms, have been employed to identify the most efficient solution to the issue.[46]

However, as the number of cities grows, the calculation required to determine the answer gets more challenging. Despite the computing challenge, we may employ approaches such as evolutionary algorithms and tabu search to find a solution that is close to optimum for thousands of towns.

2.12. VEHICLE ROUTING PROBLEM

The courier's fundamental activity is supply chain logistics. Transportation is critical to this logistics management since it is the main cost component of its operations, accounting for about 50%-60% of overall logistics expenditures. [47]

Along with transportation expenses, the timeliness of transportation operations is critical in situations when the transport process must be shortened [3]. As a result, many studies were done with the goal of reducing transportation costs while increasing the efficiency of the transportation process. Reduced transportation costs allow for a reduction in the price of items or services delivered, allowing for easier competition with rivals. This is corroborated by Ravindran and Donald [4], who claim that in order to increase sales outcomes via competitive price to market, process expenses along the supply chain must be lowered, one of which being transportation costs.

According to [13], transportation expenses are roughly classified into two categories: fixed costs and variable costs. Set costs are the normal expenses incurred by the business on a fixed nominal basis each period, ensuring that their nature is independent. Fixed transportation expenditures include vehicle acquisition and management. While the variable cost is fixed, the nominal cost is depending on the mode of transport, referred to as the dependent cost. Variable transportation expenses include those associated with fuel, labour pay, maintenance, and handling. It should be noted that how transportation cost components are classified is determined by corporate policy. Between the two forms of transportation costs, variable costs have a greater impact on the magnitude of total transportation expenses than fixed costs do [5]. Numerous studies have been conducted in order to determine the shortest path possible in order to decrease transportation variable costs. Lee and Ji [6] discussed the most generally used approach for determining the shortest route, the Traveling Salesman Problem (TSP) model and the Vehicle Routing Problem (VRP).

Both models are developed utilizing heuristic and metaheuristic methods to find the optimal answer.

2.13. VRP FOR PARCEL DELIVERY SERVICES

A courier delivers papers or goods locally or internationally. Customers' parcels are collected one by one and loaded into courier vans for sorting and delivery to other customers. Courier service is required to be rapid and exact in its operations, thereby contributing to total courier service quality improvement.

VRP for courier services is an essential and tough role. Because the customer data used in the routing process changes every day. As a consequence, repeat trips along the same route will be rare. The regulated package types will also change every day. That's what separates VRP for couriers from VRP for manufacturers or distributors. Choosing the best VRP approach for the courier is crucial to determining the quickest route.

CHAPTER THREE
DATA COLLECTION, VALIDATION, ANALYSIS AND RESULTS

3.1. METHODOLOGICAL APPROACH

The research was carried out in both quantitative and qualitative approaches. Results generated based on computation including TSP and VRP solutions of these numerical data. However, some suggestions in this research were given in a qualitative approach based on the interviews and participant observation.

3.2. DATA COLLECTION PROCEDURE

The numerical data used in this research about the warehouse design dimensions, warehouse handling parameters, daily inbound and outbound parcel generation in different routes and distance between all delivery zones were collected through field surveys and from existing official sources. To acquire a better understanding of the opportunities for improving the results, semi-structured interviews were performed with the employees and workers working in the companies under the case study.

3.2.1. Warehouse Case Study

A site visit to two warehouses of two renowned companies in Bangladesh was done as a part of this research. Flaws in their design layout and operations were assessed and short to long term recommendations were suggested. These recommendations will show up as recommendations for any other e-commerce/ logistics service or any other company willing to design and operate a warehouse in Bangladesh with more efficiency and better performance.

Case Study I: Warehouse of one of the renowned logistics service companies in Bangladesh.

The warehouse situated on the outskirts of Dhaka city serves as the mother hub for one of the leading logistics service companies in Bangladesh. Though this warehouse has been serving as the mother hub for the respective company there are many flaws in its design layout and operation which the researchers have been capable to assess.

Problems with the Current layout: The current layout of the warehouse of this company is shown in figure 7.

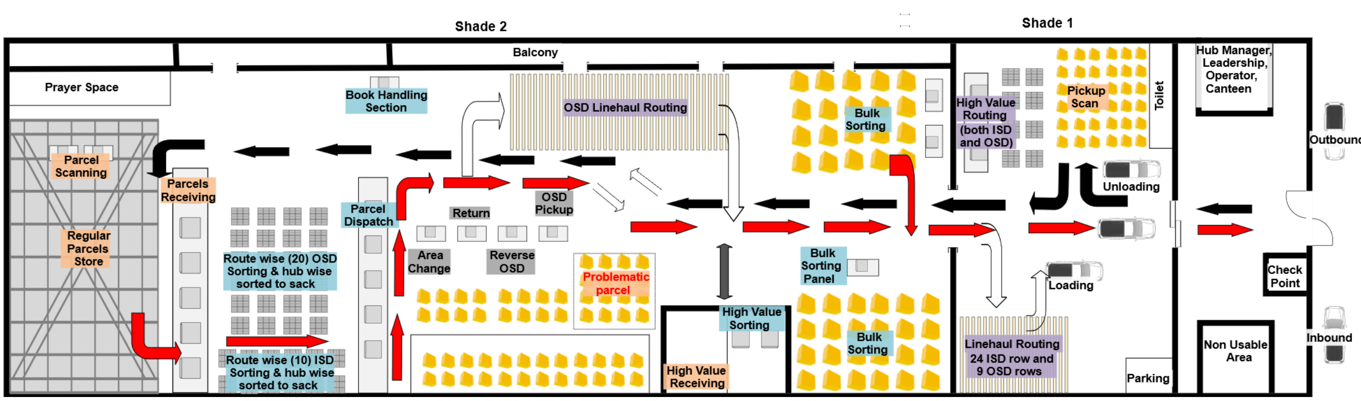

Figure 7: Existing Layout of the mother-hub of the Case Study - I

Flaws in their current warehouse operation:

I. Redundant activities: The daily operations consisted of the items and pallets travelling across multiple intermediate zones within the warehouse. Even though these actions may be less obvious, in the long run, they account for great inefficiencies. Moreover, it has been noticed that duplication of data entries at multiple stages is a major wastage of time and resources.

II. Suboptimal Picking: The warehouse greatly relies on manual labour to conduct the processes in the warehouse. A large number of human resources are employed in several shifts to carry out the picking and packing. First of all, the large number of people clustered in a given area conducting a relatively simple task of placing the items in their designated region of dispatch is inefficient and may lead to mistakes in the form of wrong placement, double handling, and increased movement. In addition, the items are seen to be 'thrown' from one person to the other while placing them in the correct route-wise and hub-wise sorting sacks. This leads to damage to the items and the packaging itself since the items are not taken proper care of.

III. Poor Layout/Space Utilization: Proper space utilization has become increasingly important with the development of e-commerce. In fulfilment facilities, an inefficient layout increases the costs of mobility and selection. Furthermore, warehouses located near densely populated areas frequently occupy more expensive land, increasing operating costs.
It may be possible to rearrange the most frequently selected items in storage locations in order to shorten the distance between them. Inquire about how new racking and storage technologies might be able to improve utilization. Perhaps a high-density automated storage and retrieval system (AS/RS) could be of assistance.
The layout of the fulfilment centre is not optimal for efficient movement and picking. The distance from the unloading zone to the receiving zone for sorting is considerably high (opposite end of the warehouse). Carrying the items across the warehouse to the picking zone and back to the initial place for loading is a major sign of inefficiency.

IV. Receiving: The receiving dock consists of an overcrowded zone where the incoming items are unloaded manually. The time taken to unload the trucks is high, which creates accumulation and the time taken to clear the docks increases. An incorrect number of personnel allocated to these tasks increases labour costs and the time taken to complete the process.

V. Return: The designated area for the returned items is quite indistinct and, due to the unprecedented rise in demand as well as the returned products, a steady stack builds up over time. The inflow of the items exceeds the outflow, leading to a haphazard situation. Lead time increases considerably and merchants receive their returned items quite late.

Case Study II: Warehouse of one of the renowned electrical appliances companies in Bangladesh.

This study was conducted in a warehouse of a reputed electronic company in order to analyse the current setting of a typical storage facility in Bangladesh. This study enhanced our conception of the current scenario of warehousing, leading to a more thorough understanding of the drawbacks that lie within.

Possible observations and challenges are the following:

I. Less visibility on real-time operation: It was noticed that the office space in this particular warehouse was in an inconvenient location. The decision was made to investigate further. It was tucked away in a back corner of the warehouse, with no view of the actual activity going on around it.

II. Dust pollution: The health and well-being of warehouse employees should be the first priority of any warehouse owner. A very small amount of dust can cause COPD, Silicosis, Asthma, Allergies, Conjunctivitis, and other skin disorders in susceptible individuals. Nobody wants to receive a product that has been contaminated with dust. Dust accumulates on products that are stored on shelves in a dusty warehouse. Many warehouses use a Last In, First Out (LIFO) inventory system, which means that some products can sit in a warehouse for an extended period of time, collecting dust and collecting more dust. Dust can also be detrimental to operating equipment. Dust can cause damage to bearings, control panels, air intakes, and electrical circuits, as well as obstruct the view of cameras and sensors when they are in use. A dusty floor may also make it difficult for robots to navigate and lose traction.

III. No defective product zones: Damaged items cost warehouse operations money. This may be avoided by utilizing pallets that can be stacked and wrapped. It is also recommended to have safe, clean, and well-lit facilities to safeguard both personnel and their goods. But in this case study, we found that they don’t have any defective product zone and it costs space.

IV. Limited Space: The problem with not having enough space is that things will continue to accumulate in an unorganized manner, which may result in workplace accidents, increased time spent identifying products, and a reduction in the overall quality of the merchandise.

    The storage systems, default selection routes, and layouts of spaces and shelves must all be optimized to make the best possible use of the available space, particularly in the welcome area, in order to make the most of this resource. The use of vertical space to its full potential increases the efficiency of material picking and packing activities while reducing inventory and operating costs.

V. FIFO method couldn’t be maintained strictly: In order to avoid poor space utilization and the difficulty of preventing a newer pallet from being placed on top of an older pallet for them, the first-in, first-out (FIFO) method has not been strictly followed. First-in, first-out inventory control has the potential to completely transform the way a warehouse operates, among other things, by reducing waste, improving customer service, and driving better performance from any warehouse. For the vast majority of businesses, it is the most advantageous option due to the wide range of benefits it provides to them.

VI. Low traceability and connectivity: We now know who manufactured the raw materials, who transported them, to whose lot they belonged, when and where they went, as well as who was in command. The problem arises when we need to record every step of the chain in order to get the most data possible.
This issue may result in a loss of control over products and supplies. Modern software, apps, and tools assist in the planning and execution of the supply chain by connecting people and resources both within and outside the warehouse. The integration of the AS/RS/WMS systems undoubtedly makes the order fulfilment process more transparent and easier.

Recommendations:

Implementation of the FIFO method completely:

i. *Make Older Items Easily Accessible*

Pallets stacked or placed in rack positions more than one pallet deep need specific considerations during put-away. These include keeping merchandise directly or at least conveniently accessible.

ii. *Stack Pallets Appropriately*

If a company warehouse uses pallet stacking, be sure that no fresh pallets are stacked on top of older ones. Pickers may need to transfer a lot of stuff if older pallets are stacked below or behind newer pallets. Palletizing correctly will simplify and speed up the fulfilment process.

iii. *Label Items Clearly*

It also helps to properly mark things so operators can readily recognize older items when many products are available in the same bin.

Warehouse Dust Control: There are three main sources of dust in a warehouse; the machinery, the product/packaging and the floor itself.

Ways of eliminating dust:

i. Ventilation Systems: Dust can be effectively removed by ventilation systems, especially if the dust is suspended in the air. The polluted air is sucked through a filtering device and then bagged for collection. Ventilation systems may also eliminate odorous gases.
ii. Fogging Systems: Fogging Systems create a thin mist of water droplets into the air. When the small water droplets mix with the dust particles in the air, they become heavier and fall to the floor.
iii. Dust Seal Partitioning: Dust Seal Partitioning is one method of limiting dust distribution in a warehouse.
iv. A set of overlapping plastic panels hanging from the ceiling may be used to shut off a dusty part of the warehouse. This type of partition can minimize the investment in ventilation and fogging systems.

Creating a supplier fulfilment program enhances supplier-customer relationships in terms of product handling and delivery timeliness.

Warehouse management, labour planning, and customer satisfaction program may be set up electronically. By using dynamic slotting, it is feasible to dynamically reposition items inside the warehouse in response to demand.

While every organization has unique logistics requirements, process automation is undeniably beneficial in addressing warehouse challenges and managing this function. To prevent repeating errors, utilizing continuous improvement approaches helps not only rectify them as they occur but also examine the causes and make required changes.

Limitations related to the recommendations

If FIFO was easy, everyone would do it. Here are some of the reasons it is difficult to maintain FIFO.

I. Requires better compliance systems: In a tiny workplace, small personnel may enforce FIFO. But Human management becomes much more challenging in a conventional warehouse. The number of items entering and exiting the area, as well as the layout and accessibility of stock in a warehouse, frequently need system changes. To genuinely function, FIFO must be regularly enforced, which requires some type of automation and management system.

II. Hard to monitor at scale: Similarly, monitoring overall FIFO efforts might be tough. A huge warehouse, SKUs with thousands of components in stock in numerous locations, or significant stock turnover that necessitates continuous inventory updates will make FIFO difficult to implement. The more inventory companies have, the tougher it is to monitor. A solid system is necessary if the company wants to expand or connect to other places.

III. Rigidity: FIFO features included by certain warehouse management systems might be too inflexible for organizations that don't match a specific mould. This may be a major issue for commodities having expiry dates, such as food, drinks, medications, or even old technology. The FIFO ethos is great, but selections must be guided by factors other than receipt date.

A smart management system can account for things that don't fit into the FIFO model and items that need to be cycled out of stock at defined intervals. It is possible that physical space will need to be redeployed

Implementing FIFO may need rearranging their present workspace. More room for rotation or a better way to rotate fresh supplies to back of stock locations might be costly and time-consuming.

3.2.2. Route Data Collection

The districts and zones were sorted using 80-20 Pareto principle based on the highest parcel generation, as provided by one of the leading logistics service companies in Bangladesh. Only 6 districts of each division under study were selected as those 20% districts have received and delivered 80% of the parcels of that specific division. The location, co-ordinates and distance between each district or zones were calculated using Google Map.

3.3. VALIDATION OF COLLECTED DATA

The validity of the data was established as follows:

I. It was provided and scrutinized by experienced supply chain professionals of renowned companies. Details biography of the the personnel's is given in Appendix A.

II. The supervisor of the study provided advice on items to be reshaped, deleted or added questions.

3.4. TECHNIQUE OF DATA ANALYSIS

Logistics Route Planning: The data gathered was prepared. The objective of it was to solve the routing using Travelling Salesman Problem (TSP) and Vehicle Routing Problem (VRP). As this research is a framework for any new player in the e-commerce/ logistics service industry, the route for logistics systems was planned for four major divisions of Bangladesh including Dhaka, Chittagong, Khulna and Rajshahi. 80-20 principle was followed while selecting only 6 delivery zones of Khulna and Rajshahi with maximum parcel generation. An optimized route between these 6 delivery zones of these two respective divisions were done using TSP. For convenience and practicality, the Chittagong division was divided into two zones and two vehicles were assigned for the logistics system.

3.4.1 Implementation of Travelling Salesman Problem (TSP)

The Traveling Salesman Problem (TSP) is a well-known example of a classical combinatorial optimization problem that is straightforward to formulate but highly complex to solve.

The objective is to discover the shortest path via a collection of N vertices so that each vertice is visited precisely once. This well-known NP-hard problem cannot be solved precisely in polynomial time. In this field, heuristic algorithms have been created to solve problems related to operations research (OR). [48]

In a TSP, a set of cities/locations are listed. The shortest way to travel to all the designated locations and back to the initial point is the core purpose of this Operations Research methodology. The algorithm for TSP is illustrated below in figure 8:

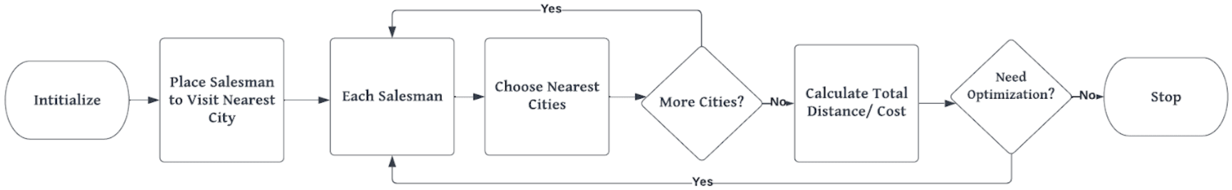

Figure 8: Algorithm of Solving Travelling salesperson problem[49]

The algorithm for the route planning using TSP using diagonal completion method as Hungarian assignment method could not solve the problem, is given below in the flowchart in figure 9:

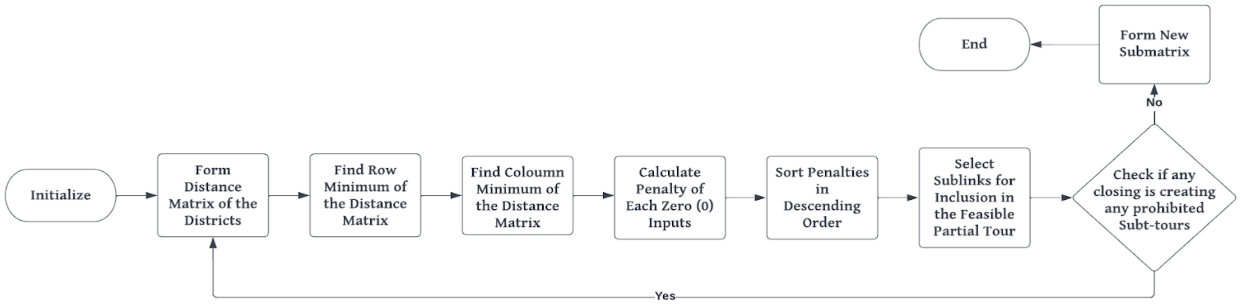

Figure 9: Flowchart of Solving TSP using Diagonal Completion Method

In our case study, we have implemented TSP for 3 major divisions of Bangladesh apart from the capital which includes Chittagong, Khulna and Rajshahi individually for each division. In each division, we have allocated 6 hubs at optimal locations from which parcels will be collected by one delivery vehicle (travelling salesperson). In the case of Chittagong, the division has been segmented into two portions with one delivery vehicle designated in each zone. The specified location of the hubs is based on the Pareto Distribution, i.e. the 80-20 principle which denotes in this scenario that 80% of the order placements arrive from 20% of the location. Hence based on the given data the decision was made.

3.4.2. Implementation of Vehicle Route Problem (VRP)

Dantzig and Ramser [50] established the Vehicle Routing Problem (VRP) in the research as the truck dispatch problem in 1959, and Lenstra and Kan verified it to be NP-hard in 1981. The classic version of the VRP entails a fleet of identical vehicles serving a group of customers along routes that start and terminate at a specific depot. The purpose of optimization is to reduce delivery costs by decreasing the total distance of all vehicles' routes. [50]

This strategy was adopted in the Dhaka Division, which has the highest parcel supply compared to the other divisions. As a result, rather than segmenting the Dhaka division into separate zones, a more efficient approach (VRP) has been established, which will take into account multiple delivery vehicles for the multiple hubs located across Dhaka city. VRP is essentially a more advanced variant of TSP. TSP only has one vehicle, whereas VRP has several. This will optimize the routes and identify the optimal number of vehicles needed to deliver the parcels. The algorithm in figure 10 below shows how the VRP approach tackles such complex logistics issues:

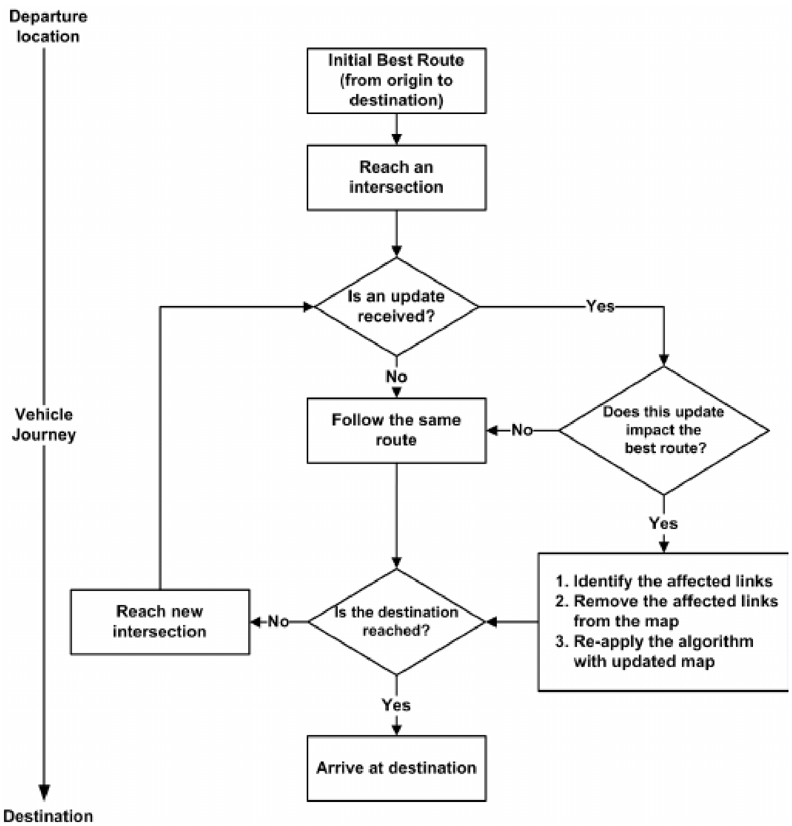

Figure 10: Algorithm of VRP [51]

3.5. COMPUTATION

3.5.1 TSP for Chittagong Division

Based on the data collected, there are many hubs distributed across the vast division. With a significant influx of parcel dispatch occurring at these hubs, employing a single delivery vehicle for the entirety of the division is not feasible. Hence the division of Chittagong has been segmented into two zones with one vehicle dedicated to each zone.

Zone 1 comprises the following areas mostly in the north of Chittagong: Comilla, Sonaimuri, Noakhali, Feni, Laxmipur and Chandpur.

Zone 2 comprises the following areas in the south of Chittagong: Cox's Bazar, Teknaf, Hathazari, Miresorai, Rangamati, Bandarban.

Zone 1:

The first zone comprises the northern areas from which according to the Pareto Distribution, the majority of the parcels arrive. The first task is to compute a distance matrix for the hubs present in zone 1 of Chittagong. The matrix will indicate the relative distance between each hub. 6

different hubs are placed at each of the indicated locations (Comilla, Sonaimuri, Noakhali, Feni, Laxmipur and Chandpur), hence the distances are denoted in the matrix.
The Number of rows = 6 and columns = 6

	Comilla	Sonaimuri	Noakhali	Feni	Lakshmipur	Chadpur
Comilla	M	49.3	97.4	59.2	90.5	69.9
Sonaimuri	49.3	M	26.7	36.9	41.7	67.9
Noakhali	97.4	26.7	M	43.2	65.2	122.4
Feni	59.2	36.9	43.2	M	65.2	122.4
Lakshmipur	90.5	41.7	38.5	65.2	M	44.2
Chadpur	69.9	67.9	86	122.4	44.2	M

Table 1 Distance matrix for Chittagong Zone 1

Hungarian method to solve the following TSP is explained down below. However, based on the calculations, this method is unable to solve the given problem.

Step 1: Each row's minimum element is determined and is subtracted from their respective row which gives the following:

	Comilla	Sonaimuri	Noakhali	Feni	Lakshmipur	Chadpur	
Comilla	M	0	48.1	9.9	41.2	20.6	(-49.3)
Sonaimuri	22.6	M	0	10.2	15	41.2	(-26.7)
Noakhali	70.7	0	M	16.5	11.8	59.3	(-26.7)
Feni	22.3	0	6.3	M	28.3	85.5	(-36.9)
Lakshmipur	52	3.2	0	26.7	M	5.7	(-38.5)
Chadpur	25.7	23.7	41.8	78.2	0	M	(-44.2)

Table 2 Matrix with row minimum subtracted from each row

Step 2: Similarly each column's minimum element is determined and subtracted from their respective columns which give the following:

	Comilla	Sonaimuri	Noakhali	Feni	Lakshmipur	Chadpur
Comilla	M	0	48.1	0	41.2	14.9
Sonaimuri	0.3	M	0	0.3	15	35.5
Noakhali	48.4	0	M	6.6	11.8	53.6
Feni	0	0	6.3	M	28.3	79.8
Lakshmipur	29.7	3.2	0	16.8	M	0
Chadpur	3.4	23.7	41.8	68.3	0	M

	(-22.3)	(-0)	(-0)	(-9.9)	(-0)	(-5.7)

Table 3 Matrix with column minimum subtracted from each column

Iteration 1 of steps 3 to 6:

Step 3: Make assignments in the opportunity cost table. Perform row-wise and column-wise scans. The following matrix denotes the assignment via row and column scans.

	Comilla	Sonaimuri	Noakhali	Feni	Lakshmipur	Chadpur
Comilla	M	0	48.1	**[0]**	41.2	14.9
Sonaimuri	0.3	M	**[0]**	0.3	15	35.5
Noakhali	48.4	**[0]**	M	6.6	11.8	53.6
Feni	**[0]**	0	6.3	M	28.3	79.8
Lakshmipur	29.7	3.2	0	16.8	M	**[0]**
Chadpur	3.4	23.7	41.8	68.3	**[0]**	M

Table 4 Matrix with row-wise and column-wise assignment (iteration 1)

Since the number of assignments is equal to the order of the matrix= 6, the solution gives the sequence: Comilla→Feni, Feni→Comilla which is not a suitable solution since the travelling salesman since each location has not been visited once.

Iteration 2 of steps 3 to 6:

The next best solution can be achieved by selecting the minimum non-zero element in the solution and repeating step 3.

Step 3: Make assignments in the opportunity cost table via row-wise scan and column-wise scan. The matrix is shown below:

	Comilla	Sonaimuri	Noakhali	Feni	Lakshmipur	Chadpur
Comilla	M	0	48.1	**[0]**	41.2	14.9
Sonaimuri	**[0.3]**	M	0	0.3	15	35.5
Noakhali	48.4	**[0]**	M	6.6	11.8	53.6
Feni	0	0	6.3	M	28.3	79.8
Lakshmipur	29.7	3.2	**[0]**	16.8	M	0
Chadpur	3.4	23.7	41.8	68.3	**[0]**	M

Table 5 Matrix with row-wise and column-wise assignment (iteration 2)

Step 4: It can be seen that the number of assignments = 5, whereas the order of the matrix =6 which is not equal, so the solution is not optimal since it is currently an unbalanced transportation problem.

Step 5: In order to convert it into a balanced transformation problem zero elements are needed to be covered with the least amount of lines. Upon completion, the matrix is as follows:

	Comilla	Sonaimuri	Noakhali	Feni	Lakshmipur	Chadpur	
Comilla	M	0	48.1	**[0]**	41.2	14.9	✓(9)
Sonaimuri	**[0.3]**	M	0	0.3	15	35.5	✓(4)
Noakhali	48.4	**[0]**	M	6.6	11.8	53.6	✓(5)
Feni	0	0	6.3	M	28.3	79.8	✓(1)
Lakshmipur	29.7	3.2	**[0]**	16.8	M	0	✓(8)
Chadpur	3.4	23.7	41.8	68.3	**[0]**	M	
	✓ (2)	✓ (3)	✓ (6)	✓ (7)		✓ (10)	

Table 6 Intermediary matrix (iteration 2)

Step 6: Develop the new revised table by selecting the smallest element, among the cells not covered by any line (say k = 11.8) Subtract k = 11.8 from every element in the cell not covered by a line. Add k = 11.8 to every element in the intersection cell of two lines.

	Comilla	Sonaimuri	Noakhali	Feni	Lakshmipur	Chadpur
Comilla	M	0	48.1	0	29.4	14.9
Sonaimuri	0.3	M	0	0.3	3.2	35.5
Noakhali	48.4	0	M	6.6	0	53.6
Feni	0	0	6.3	M	16.5	79.8
Lakshmipur	29.7	3.2	0	16.8	M	0
Chadpur	15.2	35.5	53.6	80.1	0	M

Table 7 Revised matrix

The previous steps are repeated until an optimal solution is reached.

Iteration 3 of steps 3 to 6:

Step 3: Make assignments in the opportunity cost table via row-wise scan and column-wise scan. The matrix is shown below:

	Comilla	Sonaimuri	Noakhali	Feni	Lakshmipur	Chadpur
Comilla	M	~~0~~	48.1	**[0]**	29.4	14.9
Sonaimuri	~~0.3~~	M	**[0]**	~~0.3~~	3.2	35.5
Noakhali	48.4	**[0]**	M	6.6	~~0~~	53.6
Feni	**[0]**	~~0~~	6.3	M	16.5	79.8
Lakshmipur	29.7	3.2	~~0~~	16.8	M	**[0]**
Chadpur	15.2	35.5	53.6	80.1	**[0]**	M

Table 8 Matrix with row-wise and column-wise assignment (iteration 3)

Step 4: Number of assignments = 6, order of the matrix = 6
The solution gives the sequence: ***Comilla→Feni,Feni→Comilla*** which is not a suitable solution since the travelling salesman since each location has not been visited once.

Iteration 4 of steps 3 to 6:

The next best solution can be achieved by selecting the minimum non-zero element in the solution and repeating step 3.

Step 3: Make assignments in the opportunity cost table via row-wise scan and column-wise scan. The matrix is shown below:

	Comilla	Sonaimuri	Noakhali	Feni	Lakshmipur	Chadpur
Comilla	M	**[0]**	48.1	~~0~~	29.4	14.9
Sonaimuri	~~0.3~~	M	~~0~~	**[0.3]**	3.2	35.5
Noakhali	48.4	~~0~~	M	6.6	**[0]**	53.6
Feni	**[0]**	~~0~~	6.3	M	16.5	79.8
Lakshmipur	29.7	3.2	**[0]**	16.8	M	~~0~~
Chadpur	15.2	35.5	53.6	80.1	~~0~~	M

Table 9 Matrix with row-wise and column-wise assignment (iteration 4)

Step 4: It can be seen that the number of assignments = 5, whereas the order of the matrix =6 which is not equal, so the solution is not optimal since it is currently an unbalanced transportation problem.

Step 5: In order to convert it into a balanced transformation problem zero elements are needed to be covered with the least amount of lines. Upon completion, the matrix is as follows:

	Comilla	Sonaimuri	Noakhali	Feni	Lakshmipur	Chadpur	
Comilla	M	**[0]**	48.1	0	29.4	14.9	✓(5)
Sonaimuri	0.3	M	0	**[0.3]**	3.2	35.5	✓(7)
Noakhali	48.4	0	M	6.6	**[0]**	53.6	✓(3)
Feni	**[0]**	0	6.3	M	16.5	79.8	✓(10)
Lakshmipur	29.7	3.2	**[0]**	16.8	M	0	✓(11)
Chadpur	15.2	35.5	53.6	80.1	0	M	✓(1)
	✓ (8)	✓ (4)	✓ (9)	✓ (6)	✓ (2)	✓ (12)	

Table 10 Intermediary matrix (iteration 4)

It can be seen that each element is covered with lines, hence no solution is found. Therefore diagonal completion method is employed to compute the following TSP.

Step 1: Determine each minimum row element and subtract it from their respective rows.

	1	2	3	4	5	6	
1	M	0	48.1	9.9	41.2	20.6	(-49.3)
2	22.6	M	0	10.2	15	41.2	(-26.7)
3	70.7	0	M	16.5	11.8	59.3	(-26.7)
4	22.3	0	6.3	M	28.3	85.5	(-36.9)
5	52	3.2	0	26.7	M	5.7	(-38.5)
6	25.7	23.7	41.8	78.2	0	M	(-44.2)

Table 11 Matrix with row minimum subtracted from each row

Step2: Determine each minimum column element and subtract it from their respective columns.

	1	2	3	4	5	6
1	M	0	48.1	0	41.2	14.9
2	0.3	M	0	0.3	15	35.5
3	48.4	0	M	6.6	11.8	53.6
4	0	0	6.3	M	28.3	79.8
5	29.7	3.2	0	16.8	M	0
6	3.4	23.7	41.8	68.3	0	M
	(-22.3)	(-0)	(-0)	(-9.9)	(-0)	(-5.7)

Table 12 Matrix with column minimum subtracted from each column

Step 3: Penalties for all 0s are found. Penalty (of each 0) = minimum element of that row + minimum element of that column. The matrix denotes the penalties for all 0s.

	1	2	3	4	5	6
1	M	0(0)	48.1	0(0.3)	41.2	14.9
2	0.3	M	0(0.3)	0.3	15	35.5
3	48.4	0(6.6)	M	6.6	11.8	53.6
4	0(0.3)	0(0)	6.3	M	28.3	79.8
5	29.7	3.2	0(0)	16.8	M	0(14.9)
6	3.4	23.7	41.8	68.3	0(15.2)	M

Table 13 Matrix with Penalties for all 0s

Step 4: The penalties are listed P(i,j) in descending order by value:

$P(6,5)=15.2$

$P(5,6)=14.9$

$P(3,2)=6.6$

$P(1,4)=0.3$

$P(2,3)=0.3$

$P(4,1)=0.3$

$P(1,2)=0$

$P(4,2)=0$

$P(5,3)=0$

Step 5: The links (6,5),(3,2),(1,4),(5,3) are selected for inclusion in the feasible partial tour.

Step 6: Feasible partial tour contains the following chains
6→5→3→2,1→4
(2,6),(4,1) can not be selected, because they are the closing links and create prohibited sub-tours.

Step 7: The new submatrix formed is as follows:

	6	1
2	M	49.3
4	122.4	M

Table 14 Submatrix after considering a feasible partial tour

Steps from 1 to 7 will be repeated to find the final optimal route:

Step 1: Determine each minimum row element and subtract it from their respective rows.

	6	1	
2	M	0	(-49.3)
4	0	M	(-122.4)

Table 15 Matrix with row minimum subtracted from each row

Step 3: Penalties for all 0s are found. Penalty (of each 0) = minimum element of that row + minimum element of that column. The matrix denotes the penalties for all 0s:

	6	1
2	M	0(0)
4	0(0)	M

Table 16 Matrix with Penalties for all 0s

Step 4: The penalties are listed P(i,j) in descending order by value:

P(2,1)=0

P(4,6)=0

Step 5: The links (2,1), and (4,6) are selected for inclusion in the feasible partial tour.

Step 6: A feasible partial tour contains the following chains
6→5→3→2→1→4→6
Therefore, after computing the most optimized path is determined using the diagonal completion method in this TSP for Chittagong Zone 1. The most optimized route for this zone is hence:

Chadpur→Lakshmipur→Noakhali→Sonaimuri→Comilla→Feni→Chadpur.

Following this route will ensure the shortest distance travelled in the most efficient manner which will serve to be economical for the logistics company.

The total distance thus computed is 44.2+38.5+26.7+49.3+59.2+122.4= 340.3km

Similarly, the Diagonal Completion method is applied to the remaining zone and Division stated previously to solve the TSP.

Zone 2
The second zone comprises the southern areas in Chittagong from which according to the Pareto Distribution, the majority of the parcels arrive. The first task is to compute a distance matrix for the hubs present in zone 2 of Chittagong. The matrix will indicate the relative distance between each hub. 6 different hubs are placed at each of the indicated locations (Cox's Bazar, Teknaf, Hathazari, Miresorai, Rangamati, Bandarban), hence the distances are denoted in the matrix.

	Cox's Bazar	Teknaf	Hathazari	Mirersorai	Rangamati	Bandarban
Cox's Bazar	M	78.8	161.2	199.5	199.6	116.2
Teknaf	78.8	M	231.9	270.3	271.1	187
Hathazari	161.2	231.9	M	64.2	51	83.2
Mirersorai	199.5	270.3	64.2	M	113.5	129.4
Rangamati	199.6	271.1	51	113.5	M	75.9
Bandarban	116.2	187	83.2	129.4	75.9	M

Table 17 Distance matrix for Chittagong Zone 2

The previous calculations implemented in Zone 1 of Chittagong (4.1.1.1) will be applied in this case as well and upon computation, the following route is evaluated as the most optimized:

1→2→3→4→5→6→1

Hence, if any logistics company opts to set up hubs in Chittagong zone 2, the following route is required to be followed:

<u>Cox's Bazar→Teknaf→Hathazari→Miresorai→Rangamati→Bandarban→Cox's Bazar</u>

Using this route will ensure the shortest distance travelled in the most efficient manner which will serve to be economical for the logistics company.

The total distance thus computed is 78.8+231.9+64.2+113.5+75.9+116.2=680.5 km

3.5.2. TSP for Khulna Division

6 hubs are located throughout the Khulna division in areas where the Pareto Distribution indicates the majority of shipments arrive. The first goal is to generate a distance matrix for the Khulna division's hubs. The matrix will indicate the distance between each hub compared to the others. Six distinct hubs are located in each of the indicated sites (Khulna, Kushtia, Jessore, Bagerhat, Jhenidah, Satkhira), as shown by the matrix's distances.

	Khulna	Kushtia	Jessore	Bagerhat	Jhenidah	Satkhira
Khulna	M	148.9	65.1	39.9	104	61.5
Kushtia	148.9	M	93.1	186	45	159
Jessore	65.1	93.1	M	102	46.2	69.8
Bagerhat	39.9	186	102	M	143	86.7
Jhenidah	104	45	46.2	143	M	111
Satkhira	61.5	159	69.8	86.7	111	M

Table 18 Distance matrix for Khulna

The calculations implemented in part 4.1.1.1 will be applied in this case as well and upon computation, the following route is evaluated as the most optimized:

2→5→3→6→1→4→2

Hence, if any logistics company opts to set up hubs in Khulna, the following route is the best route that can be taken:

<u>Kushtia→Jhenidah→Jessore→Satkhira→Khulna→Bagerhat→Kushtia</u>

Using this route will ensure the shortest distance travelled in the most efficient manner which will serve to be economical for the logistics company.

The total distance thus computed is 45+46.2+69.8+61.5+39.9+186= 448.4km

3.5.3. TSP for Rajshahi Divsion

6 hubs are located throughout the Rajshahi division in areas where the Pareto Distribution indicates the majority of shipments arrive. The first goal is to generate a distance matrix for the Rajshahi division's hubs. The matrix will indicate the distance between each hub compared to the others. Six distinct hubs are located in each of the indicated sites (Rajshahi, Natore, Bogra, Naogaon, Ishwardi, and Siraganj), as shown by the matrix's distances.

	Rajshahi	Natore	Bogra	Naogaon	Ishwardi	Sirajganj
Rajshahi	M	42.3	112.8	80.7	82.2	130.1
Natore	42.3	M	69.3	54.1	41.6	89.4
Bogra	112.8	69.3	M	49.5	100.6	62.9
Naogaon	80.7	54.1	49.5	M	93.9	111.5
Ishwardi	82.2	41.6	100.6	93.9	M	89.6
Sirajganj	130.1	89.4	62.9	111.5	89.6	M

Table 19 Distance matrix for Rajshahi

Here, Number of assignments = 6, number of rows = 6

Optimal assignments are

	Rajshahi	Natore	Bogra	Naogaon	Ishwardi	Sirajganj
Rajshahi	M	0	62.6	**[3.8]**	5.3	39.8
Natore	**[0]**	M	54.4	12.5	0	34.4
Bogra	62.6	54.4	M	0	51.1	**[0]**
Naogaon	3.8	12.5	**[0]**	M	17.7	21.9
Ishwardi	5.3	**[0]**	51.1	17.7	M	0
Sirajganj	39.8	34.4	0	21.9	**[0]**	M

The calculations implemented in part 4.1.1.1 will be applied in this case as well and upon computation, the following route is evaluated as the most optimized:

1→4→3→6→5→2→1

Hence, if any logistics company opts to set up hubs in Rajshahi, the following route is required to be followed:

Rajshahi→Naogaon→Bogra→Sirajganj→Ishwardi→Natore→Rajshahi

Using this route will ensure the shortest distance travelled in the most efficient manner which will serve to be economical for the logistics company.

The total distance thus computed is 80.7+42.3+62.9+49.5+41.6+89.6= 366.6km

3.5.4 VRP for Dhaka Division

The VRP for Dhaka will be calculated using Python and the OR-Tools library. The following locations have been identified as hubs across the Dhaka division based on data. Three potential mother-hubs (depots) are initially shortlisted and iterated three times to find the optimal site for the central depot (the location where all vehicles start and end their routes). This is the one that will result in the shortest total distance. As a result, the hubs are positioned in the following locations:

1. Malibagh
2. Kamlapur
3. Kalabagan
4. Mahakhali
5. Old Dhaka
6. Jatrabari
7. Keraniganj
8. Kuril
9. Demra
10. Mirpur
11. Dakshinkhan
12. Uttara
13. Tongi
14. Savar

Malibagh, Mahakhali and Azimpur are used as central depots at 3 different iterations to check for the best central depot. These areas are selected based on their geographic location and interconnectivity with the rest of the hubs.

Formulating the distance matrix is the first step in solving the problem. The data is in kilometres and was derived from Google Maps. It's a collection of distances between points. The distance callback, which returns the distances between places, is created by a function and passed to the solver. The arc charges, which specify the expense of travel, are likewise specified to be the arc distances. The distance matrix with Mahakhali as the central depot is tabulated below:

Distance Matrix:

	Mali bagh	Ka mal a pur	kala bag an	azi mpu r	mah akh ali	Old dha ka	Jatr a bari	ker ani gan j	kur il	dem ra	Mir pur	Dakshi n khan	uttara	Ton gi	Sa var
Malibagh	0	2.1	3.8c e	4.5	4.7	4.9	5.4	6	8.7	10	11	14	18	20	24
Kamlapu r	2.1	0	5.7	5.1	6.7	5	3.4	5.5	11	8	13	16	20	22	26
Kalabagan	3.8	5.7	0	2.6	5.4	3.3	8.4	7.4	11	14	9	14	16	20	21
Azimpur	4.5	5.2	2.6	0	6.7	1	6.1	5.1	13	11	11	16	18	22	22
Mohakha li	4.7	6.7	5.4	6.7	0	7.3	10	9.8	7.1	14	8.7	12	15	18	23
Old Dhaka	4.9	5	3.3	1	7.3	0	5.8	4.2	13	11	12	17	19	23	23
Jatrabari	5.4	3.4	8.4	6.1	9.8	5.8	0	5.2	14	5.4	16	19	23	25	28
Keraniga nj	6	5.5	7.5	5.1	9.7	4.2	5.2	0	15	11	16	20	23	26	27
Kuril	8.7	11	11	13	6.6	13	14	15	0	16	7.1	5.8	11	12	22
Demra	10	8	14	11	14	11	5.4	11	16	0	20	21	26	27	34
Mirpur	11	13	9	11	7.5	12	16	16	7.1	21	0	10	7.4	13	15
Dakshn khan	14	16	15	17	11	17	19	20	5.8	21	10	0	6.9	7.8	20
Uttara	18	20	16	18	14	19	23	23	11	26	7.4	6.9	0	5.4	15
Tongi	20	22	21	22	17	23	25	26	12	27	13	7.8	5.4	0	19
Savar	24	26	21	22	22	23	28	27	22	34	15	20	15	19	0

Table 20 Distance Matrix of Zones inside Dhaka

To solve this VRP, a distance dimension that calculates the total distance travelled by each delivery vehicle along its path needs to be created. The greatest of the total distances along each route is used to calculate a cost proportionate. Dimensions are used by routing applications to keep track of amounts that build along a vehicle's route.

Utilizing the solver's AddDimension method, the distance dimension is created and the argument transit_callback_index is set as the index for distance_callback.

The technique *SetGlobalSpanCostCoefficien*t sets a big coefficient (100) for the global spread of the routes, that is the maximum of the routes' distances in this case. As a result, the software prioritizes the global span in the objective function, reducing the distance of the longest route.

Finally, the route is printed denoting the total distance travelled. Initially, the count of the vehicles is set to 4. The result is as follows:

Route for vehicle 0:
0 → 4 → 1 → 9 → 6 → 7 → 5 → 3 → 2 → 0
Distance of the route: 36km

Route for vehicle 1:
0→0
Distance of the route: 0km

Route for vehicle 2:
0→12→13→11→8→0
Distance of the route: 38km

Route for vehicle 3:
0→14→10→0
Distance of the route: 45km
Total distance travelled= 36+38+45=119km

Similarly, the distance matrix is reformed with Azimpur and Malibagh as a central depot and the routes are computed. The results are computed below. Note- The indexing of the route in all the iterations is based on iteration 1, i.e. Mahakhali as a central depot.

	Routes Taken				
Central Depot	Vehicle 0	Vehicle 1	Vehicle 2	Vehicle 3	Total Distance(km)
Mohakhali	0 → 4 → 1 → 9 → 6 → 7 → 5 → 3 → 2 → 0	0→0	0→12→13→11 →8→0	0→14→10 →0	119
Azimpur	0 → 5 → 7 → 6 → 9 → 1 → 3 → 0	0 → 2 → 10 → 11 → 8 → 0	0 → 13 → 0	0 → 14 → 0	158
Malibagh	0 → 3 → 5 → 7 → 6 → 9 → 1 → 0	0 → 8 → 11 → 13 → 12 → 10 → 4 → 0	0 → 0	0 → 14 → 2 → 0	120

Table 21: Comparison of the route planning for 3 different central hubs

From the rounded data, Mohakhali is the most suitable as the central depot for Dhaka division. The VRP map in figure 12 with Mohakhali as the central depot clearly illustrates the routes that will be taken by the vehicles for the most optimized path in terms of distance.

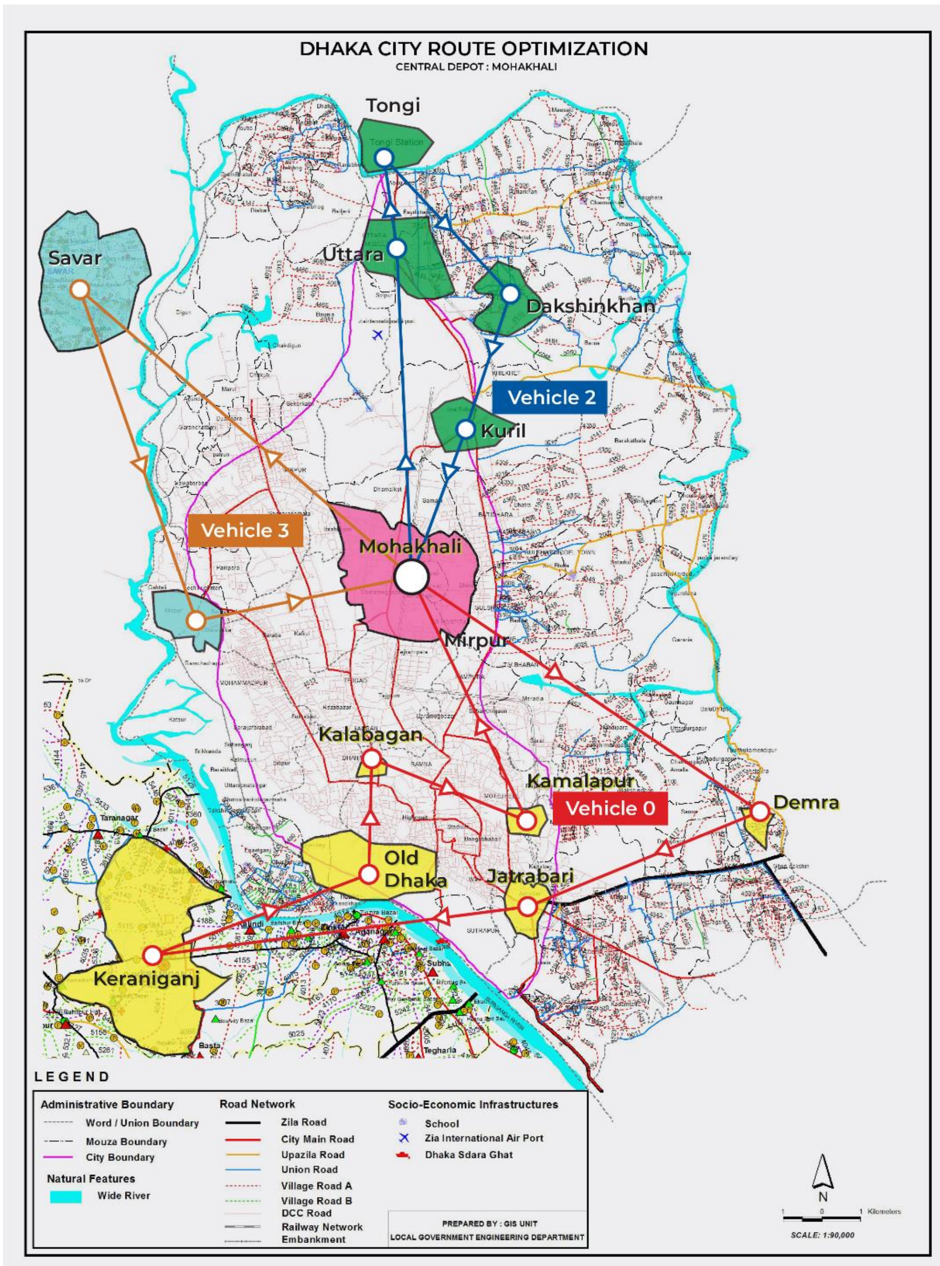

Figure 11 Optimized Route Map of Vehicles in Dhaka Division using VRP

CHAPTER FOUR
CONCLUSION AND RECOMMENDATIONS

4.1. SUMMARY OF THE RESULTS AND FINDINGS

We were able to determine the most efficient logistics planning approach for four divisions. A design for the new warehouse was also made available as part of the package. The authors feel that their findings may be used to develop a framework for logistics planning and facility design for Bangladeshi e-commerce firms.

4.2. CONCLUSION

The goal of this study was to construct a conceptual framework for warehouse design, operation, and an optimum route map among four of the country's major divisions for the logistics network of established and emerging e-commerce enterprises. The research included both quantitative and qualitative methodologies, collecting data from the real-time functioning of the logistics system at one of the nation's major logistics organizations, as well as through on-site interviews using a structured questionnaire. Upon computation using methodologies of Operation's Research a framework was generated to evaluate the best route for a set of locations which could be further modified to take into consideration live traffic data for enhanced route planning. The following research can be implemented to benefit prospective companies to grow an e-commerce business in the landscape of Bangladesh.

4.3 RECOMMENDATIONS

- The proposed layout for an enhanced warehouse system generated by our findings can be implemented in the current warehouse systems in Bangladesh to solve some existing bottlenecks persisting at the moment. The change in efficiency in terms of time and cost can be then calculated and further iterations can be made.
- In case of route planning, the computation generated can not only be implemented in Bangladesh for any prospective new-comer in e-commerce industry but also outside Bangladesh.
- An enhanced form of VRP known as dynamic VRP can be implemented which takes into consideration live traffic condition to optimize routes dynamically. This can be integrated into an app or website which will enable the user to place any set of locations which would give an optimized route for the set of data.
- New comers should iterate with multiple options for central depots to find the best possible location to place this collection and dispatch zone.

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APPENDICES

VRP Programming while taking Mohakhali as a center:

The coding part was done with the help of Google OR-Tools.

Here,
0: Mohakhali
1: kamalapur
2: kalabagan
3: Azimpur
4: Malibagh
5: old dhaka
6: jatra bari
7: keraniganj
8: Kuril
9: Demra
10: Mirpur
11: Dakshinkhan
12: Uttara
13: Tongi
14: Savar

Code:

```
Simple Vehicles Routing Problem (VRP).

   This is a sample using the routing library python wrapper to solve a VRP problem.

   Distances are in kilo-meters.

    Here,
   0: Mohakhali            8: Kuril
   1: kamlapur             9: Demra
   2: kalabagan           10: Mirpur
   3: Azimpur             11: Dakshinkhan
   4: Malibagh            12: Uttara
   5: old dhaka           13: Tongi
   6: jatra bari          14: Savar
   7: keraniganj

"""

from ortools.constraint_solver import routing_enums_pb2
from ortools.constraint_solver import pywrapcp


def create_data_model():
    """Stores the data for the problem."""
    data = {}
    data['distance_matrix'] = [
        [
           0, 6.7, 5.4, 6.7, 4.7, 7.3, 10, 9.8, 7.1, 14, 8.7,
            12, 15, 18, 23
```

```
],
[
  6.7, 0, 5.7, 5.1, 2.1, 5, 3.4, 5.5, 11, 8, 13,
  16, 20, 22, 26
],
[
  5.4, 5.7, 0, 2.6, 3.8, 3.3, 8.4, 7.4, 11, 14, 9,
  14, 16, 20, 21
],
[
  6.7, 5.2, 2.6, 0, 4.5, 1, 6.1, 5.1, 13, 11, 11,
  16, 18, 22, 22
],
[
  4.7, 2.1, 3.8, 4.5, 0, 4.9, 5.4, 6, 8.7, 10, 11, 14,
  18, 20, 24
],
[
  7.3, 5, 3.3, 1, 4.9, 0, 5.8, 4.2, 13, 11, 12,
  17, 19, 23, 23
],
[
  9.8, 3.4, 8.4, 6.1, 5.4, 5.8, 0, 5.2, 14, 5.4, 16,
  19, 23, 25, 28
],
[
  9.7, 5.5, 7.5, 5.1, 6, 4.2, 5.2, 0, 15, 11, 16,
  20, 23, 26, 27
],
[  6.6, 11, 11, 13, 8.7, 13, 14, 15, 0, 16, 7.1,
  5.8, 11, 12, 22
],
[
  14, 8, 14, 11, 10, 11, 5.4, 11, 16, 0, 20,
  21, 26, 27, 34
],
[
  7.5, 13, 9, 11, 11, 12, 16, 16, 7.1, 21, 0,
  10, 7.4, 13, 15
],
[
  11, 16, 15, 17, 14, 17, 19, 20, 5.8, 21, 10,
  0, 6.9, 7.8, 20
],
[
  14, 20, 16, 18, 18, 19, 23, 23, 11, 26, 7.4,
  6.9, 0, 5.4, 15
],
```

```
        [
            17, 22, 21, 22, 20, 23, 25, 26, 12, 27, 13,
            7.8, 5.4, 0, 19
        ],
        [
            22, 26, 21, 22, 24, 23, 28, 27, 22, 34, 15,
            20, 15, 19, 0
        ],
    ]
    data['num_vehicles'] = 4
    data['depot'] = 0
    return data


def print_solution(data, manager, routing, solution):
    """Prints solution on console."""
    print(f'Objective: {solution.ObjectiveValue()}')
    max_route_distance = 0
    for vehicle_id in range(data['num_vehicles']):
        index = routing.Start(vehicle_id)
        plan_output = 'Route for vehicle {}:\n'.format(vehicle_id)
        route_distance = 0
        while not routing.IsEnd(index):
            plan_output += ' {} -> '.format(manager.IndexToNode(index))
            previous_index = index
            index = solution.Value(routing.NextVar(index))
            route_distance += routing.GetArcCostForVehicle(
                previous_index, index, vehicle_id)
        plan_output += '{}\n'.format(manager.IndexToNode(index))
        plan_output += 'Distance of the route: {}km\n'.format(route_distance)
        print(plan_output)
        max_route_distance = max(route_distance, max_route_distance)
    print('Maximum of the route distances: {}km'.format(max_route_distance))



def main():
    """Entry point of the program."""
    # Instantiate the data problem.
    data = create_data_model()

    # Create the routing index manager.
    manager = pywrapcp.RoutingIndexManager(len(data['distance_matrix']),
                                           data['num_vehicles'], data['depot'])

    # Create Routing Model.
    routing = pywrapcp.RoutingModel(manager)
```

```
    # Create and register a transit callback.
    def distance_callback(from_index, to_index):
        """Returns the distance between the two nodes."""
        # Convert from routing variable Index to distance matrix NodeIndex.
        from_node = manager.IndexToNode(from_index)
        to_node = manager.IndexToNode(to_index)
        return data['distance_matrix'][from_node][to_node]

    transit_callback_index = routing.RegisterTransitCallback(distance_callback)

    # Define cost of each arc.
    routing.SetArcCostEvaluatorOfAllVehicles(transit_callback_index)

    # Add Distance constraint.
    dimension_name = 'Distance'
    routing.AddDimension(
        transit_callback_index,
        0,  # no slack
        3000,  # vehicle maximum travel distance
        True,  # start cumul to zero
        dimension_name)
    distance_dimension = routing.GetDimensionOrDie(dimension_name)
    distance_dimension.SetGlobalSpanCostCoefficient(100)

    # Setting first solution heuristic.
    search_parameters = pywrapcp.DefaultRoutingSearchParameters()
    search_parameters.first_solution_strategy = (
        routing_enums_pb2.FirstSolutionStrategy.PATH_CHEAPEST_ARC)

    # Solve the problem.
    solution = routing.SolveWithParameters(search_parameters)

    # Print solution on console.
    if solution:
        print_solution(data, manager, routing, solution)
    else:
        print('No solution found !')


if __name__ == '__main__':
    main()
```

Result:

```
Objective: 4619
Route for vehicle 0:
 0 ->  4 ->  1 ->  9 ->  6 ->  7 ->  5 ->  3 ->  2 -> 0
```

Distance of the route: 36km

Route for vehicle 1:
 0 -> 0
Distance of the route: 0km

Route for vehicle 2:
 0 -> 12 -> 13 -> 11 -> 8 -> 0
Distance of the route: 38km

Route for vehicle 3:
 0 -> 14 -> 10 -> 0
Distance of the route: 45km

Maximum of the route distances: 45km

VRP Programming while taking Azimpur as a center:

Here,

0 : Azimpur	8: Kuril
1: kamlapur	9: Demra
2: kalabagan	10: Mirpur
3: malibagh	11: Dakshinkhan
4: mahakhali	12: Uttara
5: old dhaka	13: Tongi
6: jatra bari	14: Savar
7: keraniganj	

Code:

```
   Distances are in kilo-meters.

   Here,
   0 : Azimpur                8: Kuril
   1: kamlapur                9: Demra
   2: kalabagan              10: Mirpur
   3: malibagh               11: Dakshinkhan
   4: mahakhali              12: Uttara
   5: old dhaka              13: Tongi
   6: jatra bari             14: Savar
   7: keraniganj

from ortools.constraint_solver import routing_enums_pb2
from ortools.constraint_solver import pywrapcp


def create_data_model():
    """Stores the data for the problem."""
```

```
data = {}
data['distance_matrix'] = [
     [
        0, 5.2, 2.6, 4.5, 6.7, 1, 6.1, 5.1, 13, 11, 11,
        16, 18, 22, 22
    ],
    [
        5.1, 0, 5.7, 2.1, 6.7, 5, 3.4, 5.5, 11, 8, 13,
        16, 20, 22, 26
    ],
    [
        2.6, 5.7, 0, 3.8, 5.4, 3.3, 8.4, 7.4, 11, 14, 9,
        14, 16, 20, 21
    ],
    [
        4.5, 2.1, 3.8, 0, 4.7, 4.9, 5.4, 6, 8.7, 10, 11, 14,
        18, 20, 24
    ],
    [
        6.7, 6.7, 5.4, 4.7, 0, 7.3, 10, 9.8, 7.1, 14, 8.7,
        12, 15, 18, 23
    ],
    [
        1, 5, 3.3, 4.9, 7.3, 0, 5.8, 4.2, 13, 11, 12,
        17, 19, 23, 23
    ],
    [
        6.1, 3.4, 8.4, 5.4, 9.8, 5.8, 0, 5.2, 14, 5.4, 16,
        19, 23, 25, 28
    ],
    [
        5.1, 5.5, 7.5, 6, 9.7, 4.2, 5.2, 0, 15, 11, 16,
        20, 23, 26, 27
    ],
    [   13, 11, 11, 8.7, 6.6, 13, 14, 15, 0, 16, 7.1,
        5.8, 11, 12, 22
    ],
    [
        11, 8, 14, 10, 14, 11, 5.4, 11, 16, 0, 20,
        21, 26, 27, 34
    ],
    [
        11, 13, 9, 11, 7.5, 12, 16, 16, 7.1, 21, 0,
        10, 7.4, 13, 15
    ],
    [
        17, 16, 15, 14, 11, 17, 19, 20, 5.8, 21, 10,
        0, 6.9, 7.8, 20
```

```
        ],
        [
            18, 20, 16, 18, 14, 19, 23, 23, 11, 26, 7.4,
            6.9, 0, 5.4, 15
        ],
        [
            22, 22, 21, 20, 17, 23, 25, 26, 12, 27, 13,
            7.8, 5.4, 0, 19
        ],
        [
            22, 26, 21, 24, 22, 23, 28, 27, 22, 34, 15,
            20, 15, 19, 0
        ],
    ]
    data['num_vehicles'] = 4
    data['depot'] = 0
    return data


def print_solution(data, manager, routing, solution):
    """Prints solution on console."""
    print(f'Objective: {solution.ObjectiveValue()}')
    max_route_distance = 0
    for vehicle_id in range(data['num_vehicles']):
        index = routing.Start(vehicle_id)
        plan_output = 'Route for vehicle {}:\n'.format(vehicle_id)
        route_distance = 0
        while not routing.IsEnd(index):
            plan_output += ' {} -> '.format(manager.IndexToNode(index))
            previous_index = index
            index = solution.Value(routing.NextVar(index))
            route_distance += routing.GetArcCostForVehicle(
                previous_index, index, vehicle_id)
        plan_output += '{}\n'.format(manager.IndexToNode(index))
        plan_output += 'Distance of the route: {}km\n'.format(route_distance)
        print(plan_output)
        max_route_distance = max(route_distance, max_route_distance)
    print('Maximum of the route distances: {}km'.format(max_route_distance))



def main():
    """Entry point of the program."""
    # Instantiate the data problem.
    data = create_data_model()

    # Create the routing index manager.
    manager = pywrapcp.RoutingIndexManager(len(data['distance_matrix']),
```

```
                                   data['num_vehicles'], data['depot'])

    # Create Routing Model.
    routing = pywrapcp.RoutingModel(manager)


    # Create and register a transit callback.
    def distance_callback(from_index, to_index):
        """Returns the distance between the two nodes."""
        # Convert from routing variable Index to distance matrix NodeIndex.
        from_node = manager.IndexToNode(from_index)
        to_node = manager.IndexToNode(to_index)
        return data['distance_matrix'][from_node][to_node]

    transit_callback_index = routing.RegisterTransitCallback(distance_callback)

    # Define cost of each arc.
    routing.SetArcCostEvaluatorOfAllVehicles(transit_callback_index)

    # Add Distance constraint.
    dimension_name = 'Distance'
    routing.AddDimension(
        transit_callback_index,
        0,  # no slack
        3000,  # vehicle maximum travel distance
        True,  # start cumul to zero
        dimension_name)
    distance_dimension = routing.GetDimensionOrDie(dimension_name)
    distance_dimension.SetGlobalSpanCostCoefficient(100)

    # Setting first solution heuristic.
    search_parameters = pywrapcp.DefaultRoutingSearchParameters()
    search_parameters.first_solution_strategy = (
        routing_enums_pb2.FirstSolutionStrategy.PATH_CHEAPEST_ARC)

    # Solve the problem.
    solution = routing.SolveWithParameters(search_parameters)

    # Print solution on console.
    if solution:
        print_solution(data, manager, routing, solution)
    else:
        print('No solution found !')


if __name__ == '__main__':
    main()
```

Result:

Objective: 4558
Route for vehicle 0:
 0 -> 5 -> 7 -> 6 -> 9 -> 1 -> 3 -> 0
Distance of the route: 29km

Route for vehicle 1:
 0 -> 2 -> 10 -> 12 -> 11 -> 8 -> 4 -> 0
Distance of the route: 41km

Route for vehicle 2:
 0 -> 13 -> 0
Distance of the route: 44km

Route for vehicle 3:
 0 -> 14 -> 0
Distance of the route: 44km

Maximum of the route distances: 44km

VRP Programming while taking Malibagh as a center:

0 : Malibagh — 8: Kuril
1: kamlapur — 9: Demra
2: kalabagan — 10: Mirpur
3: Azimpur — 11: Dakshinkhan
4: Mahakhali — 12: Uttara
5: old dhaka — 13: Tongi
6: jatra bari — 14: Savar
7: keraniganj

Code:

```
"""

   Distances are in kilo-meters.

    Here,
   0 : Malibagh                  8: Kuril
   1: kamlapur                   9: Demra
   2: kalabagan                 10: Mirpur
   3: Azimpur                   11: Dakshinkhan
   4: Mahakhali                  12: Uttara
   5: old dhaka                 13: Tongi
   6: jatra bari               14: Savar
   7: keraniganj
```

```
"""

from ortools.constraint_solver import routing_enums_pb2
from ortools.constraint_solver import pywrapcp


def create_data_model():
    """Stores the data for the problem."""
    data = {}
    data['distance_matrix'] = [
        [
            0, 2.1, 3.8, 4.5, 4.7, 4.9, 5.4, 6, 8.7, 10, 11, 14,
            18, 20, 24
        ],
        [
            2.1, 0, 5.7, 5.1, 6.7, 5, 3.4, 5.5, 11, 8, 13,
            16, 20, 22, 26
        ],
        [
            3.8, 5.7, 0, 2.6, 5.4, 3.3, 8.4, 7.4, 11, 14, 9,
            14, 16, 20, 21
        ],
        [
            4.5, 5.2, 2.6, 0, 6.7,1, 6.1, 5.1, 13, 11, 11,
            16, 18, 22, 22
        ],
        [
            4.7, 6.7, 5.4, 6.7, 0, 7.3, 10, 9.8, 7.1, 14, 8.7,
            12, 15, 18, 23
        ],
        [
            4.9, 5, 3.3, 1, 7.3, 0, 5.8, 4.2, 13, 11, 12,
            17, 19, 23, 23
        ],
        [
            5.4, 3.4, 8.4, 6.1, 9.8, 5.8, 0, 5.2, 14, 5.4, 16,
            19, 23, 25, 28
        ],
        [
            6, 5.5, 7.5, 5.1, 9.7, 4.2, 5.2, 0, 15, 11, 16,
            20, 23, 26, 27
        ],
        [   8.7, 11, 11, 13, 6.6, 13, 14, 15, 0, 16, 7.1,
            5.8, 11, 12, 22
        ],
        [
            10, 8, 14, 11, 14, 11, 5.4, 11, 16, 0, 20,
            21, 26, 27, 34
```

```
        ],
        [
            11, 13, 9, 11, 7.5, 12, 16, 16, 7.1, 21, 0,
            10, 7.4, 13, 15
        ],
        [
            14, 16, 15, 17, 11, 17, 19, 20, 5.8, 21, 10,
            0, 6.9, 7.8, 20
        ],
        [
            18, 20, 16, 18, 14, 19, 23, 23, 11, 26, 7.4,
            6.9, 0, 5.4, 15
        ],
        [
            20, 22, 21, 22, 17, 23, 25, 26, 12, 27, 13,
            7.8, 5.4, 0, 19
        ],
        [
            24, 26, 21, 22, 22, 23, 28, 27, 22, 34, 15,
            20, 15, 19, 0
        ],
    ]
    data['num_vehicles'] = 4
    data['depot'] = 0
    return data


def print_solution(data, manager, routing, solution):
    """Prints solution on console."""
    print(f'Objective: {solution.ObjectiveValue()}')
    max_route_distance = 0
    for vehicle_id in range(data['num_vehicles']):
        index = routing.Start(vehicle_id)
        plan_output = 'Route for vehicle {}:\n'.format(vehicle_id)
        route_distance = 0
        while not routing.IsEnd(index):
            plan_output += ' {} -> '.format(manager.IndexToNode(index))
            previous_index = index
            index = solution.Value(routing.NextVar(index))
            route_distance += routing.GetArcCostForVehicle(
                previous_index, index, vehicle_id)
        plan_output += '{}\n'.format(manager.IndexToNode(index))
        plan_output += 'Distance of the route: {}km\n'.format(route_distance)
        print(plan_output)
        max_route_distance = max(route_distance, max_route_distance)
    print('Maximum of the route distances: {}km'.format(max_route_distance))
```

```
def main():
    """Entry point of the program."""
    # Instantiate the data problem.
    data = create_data_model()

    # Create the routing index manager.
    manager = pywrapcp.RoutingIndexManager(len(data['distance_matrix']),
                                           data['num_vehicles'], data['depot'])

    # Create Routing Model.
    routing = pywrapcp.RoutingModel(manager)


    # Create and register a transit callback.
    def distance_callback(from_index, to_index):
        """Returns the distance between the two nodes."""
        # Convert from routing variable Index to distance matrix NodeIndex.
        from_node = manager.IndexToNode(from_index)
        to_node = manager.IndexToNode(to_index)
        return data['distance_matrix'][from_node][to_node]

    transit_callback_index = routing.RegisterTransitCallback(distance_callback)

    # Define cost of each arc.
    routing.SetArcCostEvaluatorOfAllVehicles(transit_callback_index)

    # Add Distance constraint.
    dimension_name = 'Distance'
    routing.AddDimension(
        transit_callback_index,
        0,  # no slack
        3000,  # vehicle maximum travel distance
        True,  # start cumul to zero
        dimension_name)
    distance_dimension = routing.GetDimensionOrDie(dimension_name)
    distance_dimension.SetGlobalSpanCostCoefficient(100)

    # Setting first solution heuristic.
    search_parameters = pywrapcp.DefaultRoutingSearchParameters()
    search_parameters.first_solution_strategy = (
        routing_enums_pb2.FirstSolutionStrategy.PATH_CHEAPEST_ARC)

    # Solve the problem.
    solution = routing.SolveWithParameters(search_parameters)

    # Print solution on console.
    if solution:
```

```
        print_solution(data, manager, routing, solution)
    else:
        print('No solution found !')


if __name__ == '__main__':
    main()
```

Result:

Objective: 4920
Route for vehicle 0:
 0 -> 3 -> 5 -> 7 -> 6 -> 9 -> 1 -> 0
Distance of the route: 29km

Route for vehicle 1:
 0 -> 8 -> 11 -> 13 -> 12 -> 10 -> 4 -> 0
Distance of the route: 43km

Route for vehicle 2:
 0 -> 0
Distance of the route: 0km

Route for vehicle 3:
 0 -> 14 -> 2 -> 0
Distance of the route: 48km

Maximum of the route distances: 48km

Data Collection:

The chart shows what percentage of parcel is generated from the different cities of the country over a one-month period of time. The data was collected from a renowned logistics company in the country.

Receiving_Hub	Percentage
Mirpur	24.93623%
Kalabagan	18.61943%
Malibagh	14.17890%
Mohakhali	9.21478%
Puran Dhaka	8.53775%
Uttara	4.97084%
Kuril	3.34071%
Jatrabari	3.03640%
Azimpur	2.86218%
Dakshinkhan	2.53987%
Narayanganj	1.39838%
Bhairab	0.00927%
Kamlapur	0.74277%
Keraniganj	0.59626%
Savar	0.52562%

Gopalganj	0.00437%
Tongi	0.45924%
Demra	0.43793%
Kaliakoir	0.09664%
Rupganj	0.20426%
Tangail	0.18668%
Rajbari	0.13468%
Kaliakoir	0.09664%
Kishorganj	0.05743%
Narsingdi	0.05114%
Modhupur	0.00277%
Munshiganj	0.03154%
Manikganj	0.02387%
Sreenagar	0.02088%
Faridpur	0.04081%
Madaripur	0.01396%
Shariatpur	0.00394%
Nabinagar	0.00384%
Mawna	0.03026%
Saidpur	0.01726%
Lalmonirhat	0.27821%
Dinajpur	0.06862%
Rangpur	0.03964%
Gaibandha	0.02760%
Kurigram	0.00682%
Thakurgaon	0.00618%
Nilphamari	0.00543%
Birampur	0.00501%
Panchagarh	0.00309%
Khulna	0.27224%
Kushtia	0.11071%
Jessore	0.07128%
Bagerhat	0.03324%
Jhenaidah	0.02983%
Satkhira	0.03186%
Magura	0.02120%
Chuadanga	0.01609%
Meherpur	0.00746%
Narail	0.00970%
Jessore Noapara	0.00927%
Paikgacha	0.00128%
Rajshahi	0.24336%
Natore	0.08343%
Bogra	0.07309%
Naogaon	0.06318%
Ishwardi	0.01758%
Sirajganj	0.05306%
Pabna	0.01630%

Patnitala	0.00788%
Joypurhat	0.00458%
Chapai Nawabganj	0.00341%
Cox's Bazar	0.18796%
Comilla	0.11966%
Sonaimuri	0.08673%
Noakhali	0.03335%
Lakshmipur	0.03250%
Teknaf	0.02653%
Hathazari	0.02653%
Feni	0.02621%
Chadpur	0.01620%
Miresorai	0.01470%
Brahmanbaria	0.00970%
Laksham	0.00842%
Rangamati	0.00767%
Hajiganj	0.00458%
Patiya	0.00245%
Bandarban	0.00224%
Satkania	0.00075%
Chakaria	0.00053%
Sandwip	0.00032%
Khagrachari	0.00032%
Mymensingh	0.12243%
Gouripur	0.01705%
Jamalpur	0.00820%
Valuka	0.00650%
Netrokona	0.00533%
Sherpur	0.00170%
Sylhet	0.06191%
Beanibazar	0.00948%
Moulvibazar	0.00746%
Chatak	0.00469%
Kulaura	0.00373%
Habiganj	0.00256%
Sunamganj	0.00181%
Companyganj	0.00170%
Shayestaganj	0.00117%
Barishal	0.05317%
Perojpur	0.00980%
Patuakhali	0.00938%
Barguna	0.00874%
Bhola	0.00320%
Jalokathi	0.00234%
Gournadi	0.00107%
Charfession	0.00053%
Kolapara	0.00053%