FACULTY OF MECHANICAL ENGINEERING TUL

Master Thesis

Logistic system design

Study programme: N0788A270005 Innovation and Industrial Engineering

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Thesis Supervisors: Ing. František Koblasa, Ph.D.
Department of Manufacturing Systems and Automation

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Master Thesis Assignment Form

Logistic system design

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Rules for Elaboration:

This thesis aims to design a logistic system in DZ Dražice to meet expense requirements while meeting the logistic demand given by the manufacturing system. Recommended to follow are:
1/ Analysis of Production base (e.g. ABC analysis) of defined logistic problem.
2/ Information and material flow analysis (e.g. process analysis, spaghetti diagram, material handling analysis) of selected products.
3/ Analysis of logistic operations of selected products (e.g. Day screening, chronometry, selective timing.)
4/ Design of logistic model (e.g. Capacity – Analytical model or simulation) and setting necessary resources to meet logistic demand while considering possible alternative material handling systems.
5/ Compare the designed logistic model with the current state of the system.

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List of Specialised Literature:

[1] TOMPKINS, James A., John A. WHITE, Yavuz A. BOZER a J. M. A. TANCHOCO. *Facilities planning*. Fourth edition. Hoboken: John Wiley & Sons, [2010]. ISBN 978-0-470-44404-7.
[2] STEPHENS, Matthew P. a Fred E. MEYERS. *Manufacturing facilities design and material handling*. Fifth edition. West Lafayette, Indiana: Purdue University Press, [2013]. ISBN 978-1-55753-650-1.
[3] DORF, Richard C. a Andrew KUSIAK, ed. *Handbook of design, manufacturing and automation*. New York: Wiley-Interscience Publication, John Wiley & Sons, [1994]. ISBN 0-471-55218-6.
[4] RICHARDS, Gwynne. Warehouse management: a complete guide to improving efficiency and minimizing costs in the modern warehouse. London: Kogan Page, 2011. ISBN 978-0-7494-6074-7.
[5] RUSHTON, Alan, Phil CROUCHER a Peter BAKER. The handbook of logistics & distribution management. 4th ed. London: Kogan Page, 2010. ISBN 978-0-7494-5714-3.

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ABSTRACT

This thesis addresses the logistical challenges related to truck adequacy and alternative transport systems in an industry context. Through a comprehensive analysis, including ABC analysis, process mapping, and chronometry, the study identifies valuable products, optimizes truck loading arrangements, and develops a new scheduling algorithm. The research concludes that the existing fleet of two trucks is sufficient to meet transportation needs when supported by the tested loading methods and schedule. Implementing these optimized approaches improves operations, efficiency, and cost-effectiveness. By leveraging these strategies, the existing fleet efficiently handles transportation requirements, eliminating the need for additional vehicles or alternative options. These findings contribute to a better understanding of logistical optimization by highlighting the importance of innovative loading methods and schedules for maximizing existing resources. They also lay a foundation for ongoing improvements in transportation logistics, highlighting the potential for continued enhancements in the field

Keywords: Logistic system analysis, Truck loading optimization, Transport scheduling, Capacity planning.

ABSTRAKT

Tato práce se zabývá logistickými výzvami souvisejícími s přiměřeností nákladních vozidel a alternativními dopravními systémy v průmyslovém kontextu. Prostřednictvím komplexní analýzy, včetně analýzy ABC, mapování procesů a chronometrie, studie identifikuje cenné produkty, optimalizuje uspořádání nákladních vozidel a vyvíjí nový algoritmus plánování. Výzkum došel k závěru, že stávající vozový park dvou nákladních vozidel je dostatečný k pokrytí přepravních potřeb, pokud je podporován testovanými metodami a harmonogramem nakládky. Implementace těchto optimalizovaných přístupů zlepšuje provoz, efektivitu a nákladovou efektivitu. Využitím těchto strategií stávající vozový park efektivně řeší požadavky na přepravu, čímž eliminuje potřebu dalších vozidel nebo alternativních možností. Tato zjištění přispívají k lepšímu pochopení logistické optimalizace tím, že zdůrazňují důležitost inovativních metod a harmonogramů nakládání pro maximalizaci stávajících zdrojů. Pokládají také základ pro neustálé zlepšování dopravní logistiky a zdůrazňují potenciál pro další zlepšování v této oblasti

Klíčová slova: Analýza logistického systému, Optimalizace zatížení kamionů, Plánování přepravy, Plánování kapacit,

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List of Abbreviation

AGV – Automated Guided Vehicles

CVRP - Capacitated Vehicle Routing Problem

D – Drazice

FMS - Flexible Manufacturing system

L – Lustenice

NL – New Loading

NVA – Non-Value Added

OL – Old Loading

PLT – Product Lead Time

VRP – Vehicle Routing Problem

VRPTW - Vehicle Routing Problems with Time Windows

VA – Value Added

W – Ware house

1 Introduction

A few things that keep the market of any product alive includes competitor and demand. To compete with the competitors and satisfy the existing demand, that is, to work efficiently, Industries focus on increasing the production of their product in the least possible time with optimal usage of resources with better transportation, streamlined storage, and movement of stocks. [1] Time taken for the transportation of raw materials through each process holds its part in the overall production time. The growth of a company in the market and the development of its strategies could be compromised without applying proper logistics. Precisely this project is all about logistic system design. That is to design a logistic system through which we could attain a quick and cost and time efficient transport of products.

Our project is based on the Druzstevni zavody Drazice company that is the No. 1 producer of water heaters in the Czech Republic. They produce 380 types and modifications of water heaters with vertical, horizontal, stationary, electric, and combined design in volumes from 5 to 1000 litres, and indirect stationary water reservoirs (exchangers) in volumes from 100 to 1000 litres. It consists of two production units (Drazice and Lustenice) and one warehouse. The efficient transport of finished products between the production units and the warehouse with the available resources is the one-line goal of this study. [2]

1.1 Objectives of the thesis

- To design a logistic system to the company that focus on the transport of finished products.
- To analyse if the available trucks are enough for smooth movement of materials.
- To draw a transport schedule for the trucks
- Analyse and suggest if there are need for the alternatives for the transport of materials from lustenice to warehouse that is nearly 250m far.

1.2 Logistic problem faced by the company

- Though the company should have enough material handling and transportation technologies to ensure the best possible shipping, there is now considerable uncertainty.
- Stocks are accumulated in one place and transport trucks are waiting in the other area that is improper usage of resources.

- Extra transports increase the wasteful use of energy and resources when total inventories may be transferred in a limited number of transports.
- Unstandardized transportation presents a significant forecasting challenge.
- Because there is not a sufficient transportation loop, a new driver might not be familiar with the route or the ideal timing and schedule for transportation.
- Since there is a limited inventory space in both the production areas, if the finished products are not transported on time the accumulation of products can slow down the production.
- Since the distance between Lustenice and the warehouse is rather short, alternative transportation methods may or may not be used in place of trucks because loading and unloading take a lot of time.

The development of a company is influenced by the decisions that are made when the problem is identified and alternatives are stated. Decisions also determine the economic and operational growth of an organization. The main motto of the project is to analyse the best possible solutions for certain identified problems that are stated above, and that can be done by calculations based on the details given below

1.3 Required data

- Number of workers needed to load and unload materials from and to the truck.
- Time taken for loading and unloading pallets.
- Requirement of empty pallets for every shift
- Size and dimensions of the pallet and trucks.
- Number of material handling instruments and operators required for movement of materials.
- Transport route and cost.
- Production rate and shift and break timing.
- Economic way of movement of products to the warehouse in a loop connecting, ware house, production area 1 (Drazice) and production area 2 (Lustenice) which are a bit far away from each other.

In short, this project helps us in understanding the methods and knowledge that are adopted to analyse the solutions and alternatives for logistic problems. Solutions for problems like the requirement of men and material handling instruments and time required for an operation to complete and a proper logistic design solve 80% of queries. Proper planning and designing of Logistic system and comparison of the new system with the old requires a set of knowledge on specific topics that provides us better understanding about the project are explained in this project report. Let us have a look at the basic knowledge that should be known before designing a logistic system.

2 Literature Review

A master's thesis's literature review critically evaluates the current body of knowledge on the subject of the thesis. It presents a theoretical foundation, reviews pertinent literature, and identifies knowledge gaps. It supports the research questions, establishes the study's significance, and serves as a basis for the study's methodology and data analysis.

2.1 Manufacturing system

A manufacturing system is the collection of procedures, tools, and tasks used to create items or products. It includes a number of components, including equipment use, inventory management, scheduling, and production planning. Within the manufacturing sector, it seeks to maximize efficiency, cut costs, guarantee product quality, and satisfy customer needs.

2.1.1 System

A system can be defined as a set of individual things or a group of assembled things working together with a mechanism or interconnected network. In simple words, a system is a set of principles or procedures according to which something is done. It consists of units and module. The four basic attributes that characterise the system are Assemblage, Relationship, Goal seeking, Adaptability to Environment.[3]

2.1.2 Definition of a Manufacturing system

A manufacturing system is basically a unique assemblage of hardware, which includes workers, production facilities, materials handling equipment, and other supplementary devices. The procedure of integrated manufacturing system is divided into four processes (Product Design stage, Process planning stage, Implementation stage, Production Management stage) [3]

Three flows concerning manufacturing

- Flow of materials
- Flow of information
- Flow of cost

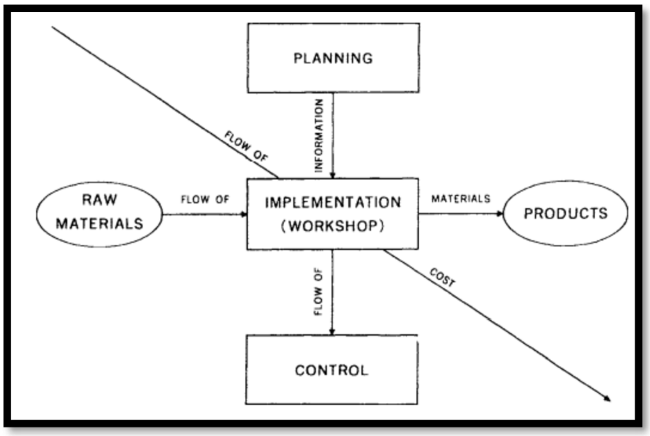


Figure 1 Three figures in manufacturing [4]

2.1.3 Manufacturing system types

Major manufacturing systems falls under these five systems,

- Custom manufacturing system – Specified product line – Military device
- Intermittent manufacturing system – Based on customer orders – machine shops.
- Continuous manufacturing system – Continuous physical flow of materials – Petrochemical industry.
- Flexible manufacturing system – Highly automated machine cell – Types (Sequential, Random, Dedicated, Engineered, Modular) FMs – Aircraft component manufacturing.
- Mass Customisation – Mass production of customised designs.[4]

2.1.4 Manufacturing layout

The physical arrangement of tools, machinery, workstations, and materials in a production plant is known as the manufacturing layout.

- The layout is created to reduce waste, lower costs, increase productivity, and optimize the flow of resources and goods through the manufacturing process.
- The type of items being manufactured, the volume of production, the amount of space and other resources that are available, and the desired degree of productivity and efficiency will all influence the factory layout that is chosen.
- Any manufacturing operation must have a well-designed production layout because it can boost productivity, lower costs, and improve product quality.[4]

2.1.5 Manufacturing is in relation with flow of materials.

- Logistic system = Material supply system + material handling system + Physical distribution system.
- Material handling system = Handling + transfer of workpiece inside factory.
- Physical distribution system = Transport and distributes goods to customer.

Considering material flow inside factory manufacturing system conducts three basic activities.

Conversion – By the activity called operation, the form of workpiece is converted. Carried out in a workstation. A project completion needs series of operation comprising multiple stage production.

Transportation – Transportation of workpiece between workstations. Commonly material handling. Reduced material handling increases manufacturing efficiency.

Transportation can be reduced by following ways_

- Reducing transfer distance
- Decreasing number of transfer activities
- Determining optimal transfer route.
- Balanced transfer activity

Storage – Stock at warehouse or temporary stock between workstations. To nullify the imbalance between the transportation and conversion. In simple words, "Delay". Storage is the stagnation of material between two successive stages of production process.[4]

- Raw material inventory
- Work in process inventory
- Finished product inventory

2.1.6 ABC analysis

ABC analysis is a method used to divide products into three groups according to their importance degree in order to manage inventory and increase productivity. The Pareto chart can be used in ABC analysis to organize elements according to their relative importance.

- A-items: According to their worth or number, these are the inventory items that are most significant. A-items typically make up a sizable portion of the total inventory of things but a smaller portion of the total value or sales revenue. To make sure they are always in stock, these items need to be closely watched and subjected to frequent inventory inspections.
- B-items are moderately significant inventory items that make up a modest portion of the total value or sales revenue. They need to be checked frequently, but not as frequently as A-items.
- C-items: In terms of their price or number, these are the least significant goods in the inventory. C-items typically make up a sizable portion of the inventory's total number of items but only a little portion of its overall value or sales revenue. Compared to items A and B, these ones can be controlled more easily and with less regular monitoring.

Items are categorized into the A, B, and C categories depending on a number of variables, including sales volume, profit margin, and the item's criticality.[4]

2.1.7 Process diagram

A process diagram is a graphic representation of a system or process that outlines the actions or activities necessary to complete a task or reach a goal. Engineering frequently employs process diagrams to aid in the analysis, design, and improvement of processes.

- The process's many steps or stages are represented by nodes or boxes. Usually, a brief summary of the process is used to mark each node.
- Arrows or lines: This shows how the process moves from one phase to the next. Depending on the particular process being diagrammed, the direction of the arrows may be from left to right, top to bottom, or in any other way.
- Branches: A process may occasionally contain several branches or routes that result in various results. These can be shown using various colour schemes, dashed lines, or other visual indicators.
- Both inputs and outputs may be present at different stages of the process, depending on the process being represented. Arrows or other symbols can be used to represent these.

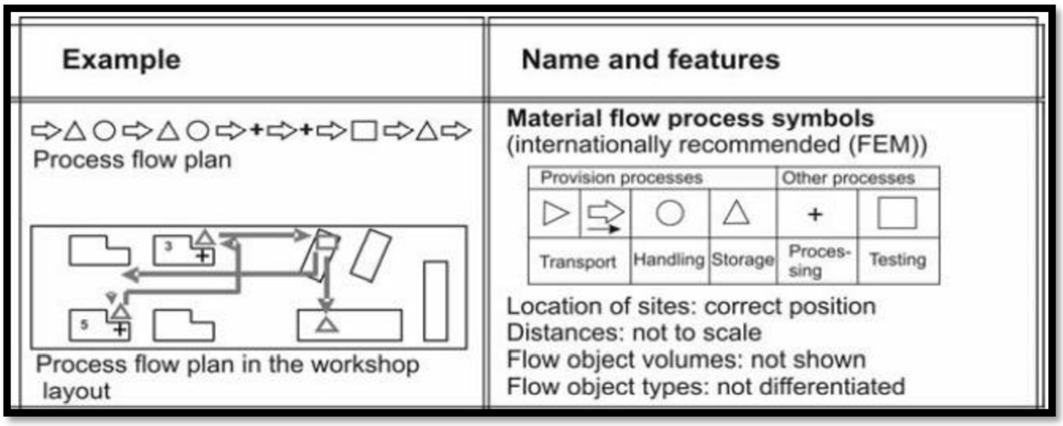


Figure 2 Process flow [5]

A range of devices and programs, including flowchart software, diagramming tools, and even a pen and paper, can be used to produce process diagrams. To aid in the visualization and comprehension of complex systems and processes, they are frequently used in project management, quality assurance, and process improvement projects.[5]

2.2 Logistic system

Transport, inventory, and warehousing are the three main pillars of logistics—have been essential aspects of industrial and economic life for countless years, but it has only been within the last 20 years or so that logistics has gained recognition as a significant function in and of itself. The nature of logistics itself is the primary reason why this awareness has only been made recently. It is a function made up of numerous sub-functions and numerous subsystems, each of which has been considered as a separate management activity and still may be. Both the academic and commercial communities increasingly acknowledge the need to adopt a more holistic perspective of these many operations in order to account for how they relate to and interact with one another.[6]

Logistics is the planning, implementation, and control of

- Movement and positioning of people or goods.
- Associated supporting activities

2.2.1 Logistic Product, Process, System

Logistics = Logistic Product + Logistic process + Logistic system + facility

This simplifies the task and also helps us in controlling the task when performed.

Logistic product

Commodities (Goods, parts, wastes, animals, people) – orders, inventory information's, Identification number.

6+1 Rights of logistics

- Right object
- Right quantity
- Right place
- Right time
- Right cost
- Right quality
- Environmentally compatible [7]

Logistic Process

Physical Perspective - Material flow, Storage, Transportation, Handling, Collecting/Distributing, Picking, Sorting, Packaging/Repacking, Labelling/Identification

Information flow – Capturing, Processing, Storing, Circulating.

Key points of process description

- Process identification – Where the process stands in the systems?
- Process Owner – Who is responsible for developing the process?
- Process participants – Who is responsible for Individual task?
- Process objective – What is the role of process?
- Process customer – Who is benefited from the outcome of process?
- Process Inputs – What initiates the process?
- Rules in Process – What specialisation and rules are there for the process?
- Process outcome – What is the output of process?
- Verification and Documentation – What information, documentation and records are needed for the process?

- Process control data – What parameters are used to control the process?
- InterAction with other process – What other process have influence on this process.
- Process supplier – Who is responsible for preparatory work for the process

Features to be described to illustrate a Logistic process

- Potential (generation of demands for goods)
- Topologies (Paths, distance and routes)
- Flow (Movement, Inventory, Blockage, Impediments)
- Resource (Floor space, volume, cost, Personal, Time)
- Restrictions [6]

2.2.2 Spaghetti diagram

A spaghetti diagram, commonly referred to as a spaghetti chart, is a picture of a workflow or process. Its name comes from how the arrows and lines that depict the movement of materials, information, or workers during the process resemble a plate of jumbled spaghetti.[4]

2.2.3 Value Stream Mapping

A value stream map is a visual representation of the process that shows each step in the creation or provision of a good or service. The map identifies all the sources of waste and inefficiency in the process and depicts the flow of materials, products, and information from the beginning to the finish of the operation.[8]

2.2.4 Chronometry

Chronometry is the exact measurement of time and the measurement of time intervals. Day chronometry is the exact estimation of time during a day or a 24-hour period by the measurement of time intervals.

Day chronometry has several applications, including scientific research, athletic events, and business operations. To effectively collect data and assess outcomes in scientific research, precise measurements of time intervals are frequently required. Accurate timing is crucial for identifying victors and setting records in athletic competitions. Timing is crucial in industrial operations to coordinate machine movements and guarantee seamless production.

- Value-Added Time, or VA time, refers to the amount of time spent really enhancing a good or service from the perspective of the client. In other words, the client is willing to pay for the time spent engaging in activities.
- The term "NVA time" refers to the amount of time spent on tasks that do not improve the value of the good or service. These tasks can include any task that does not immediately result in the generation of value for the customer, such as waiting, relocating, reworking, and so on.

Each phase of time of the process is examined to determine the VA and NVA timings, and the time spent on each activity is assigned to one of the two categories. After this study is finished, the business can pinpoint areas where NVA time can be cut back on and make adjustments to increase VA time. [9]

2.2.5 Use of transport matrix

Evaluation matrix – Distance matrix, Duration matrix, Transport matrix, Load matrix and cost matrix.

Transport distance matrix - The distances between various origin and destination places are conveniently represented by this transport distance matrix. It can be applied to a variety of tasks, including as streamlining supply chain networks, estimating transportation costs, and optimizing logistics routes.

		Starting points		Destinations (offices/sites)								
		1	2	1	2	3	4	5	6	7	8	9
Starting points	1	-	-	10.4	21.5	10.5	10	11.2	9.4	15.8	20.9	10.4
	2	-	-	6.5	21	10	9.5	4.7	4.4	6.4	17	5.5
Destinations (offices/sites)	1	10.4	6.5	-	15.1	4.1	3.7	1.8	2.1	8.5	10.5	0.65
	2	21.5	21	15.1	-	12.4	12.1	15.9	16.2	22.5	25.6	15.3
	3	10.5	10	4.1	12.4	-	0.65	4.8	9.2	11.6	14.6	4.1
	4	10	9.5	3.7	12.1	0.65	-	4.5	4.8	11.2	14.2	3.7
	5	11.2	4.7	1.8	15.9	4.8	4.5	-	0.23	6.7	12.3	0.85
	6	9.4	4.4	2.1	16.2	9.2	4.8	0.23	-	6.5	12.1	1.2
	7	15.8	6.4	8.5	22.5	11.6	11.2	6.7	6.5	-	19	7.4
	8	20.9	17	10.5	25.6	14.6	14.2	12.3	12.1	19	-	11.2
	9	10.4	5.5	0.65	15.3	4.1	3.7	0.85	1.2	7.4	11.2	-
	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Figure 3 Example of Transport Distance Matrix [10]

Identify origin and destination points. Create a matrix with rows as origins and columns as destinations. Fill in the matrix with calculated distances between each origin-destination pair. This helps us with routing and other calculations. [7]

Logistic Relationships

It is necessary to consider the relationships between the product, process and system logistics as we divide them.

- Logistic product defines the requirement of logistic system.
- Logistic product also defines the requirement of logistic process.
- The relationship coordinates the configuration and structure and sequence

Material flow planning approaches

- Problem and situation analysis plus Precise definition of project task
- Determination of functional concept – formulated as process chain
- Dimensioning
- Structuring
- Design
- Verification [11]

2.2.6 Transport

Transportation is the movement of material from one point to other. Transportation cost is influenced by Volume, Quantity and Mass of objects that must be moved and stored.

The transport process flow must define

- Amount and type of transport equipment
- Amount and type of transport utilities
- Stagnation and disposal areas
- Types and location of transport routes
- Location of buffer
- Skill level and number of workers
- Scope of all utilities

Process applied for selection of means of transport

1. Formulation of transport task – Transport (volume, time, route)
2. Selection of conveying principle (Continuous or discontinuous)
3. Specification of transport Level (Overhead, Ground based)
4. Crane track installation (Line, area, room)
5. Calculate transport load (permissible/Max load)

Picking

Picking process should always be decided before the storage process for economic movements of materials.

Storage

Larger stores and Buffer stocks can be designed separately.

Buffer can be characterized as

- Stationary buffer - Magazines
- Flowing buffer – Circular conveyers

a) **Storage functions** – Warehouse functions – Material supply, ability to deliver, Balancing quantity fluctuations
b) **Goods inward and goods outwards** – Ware house interface to surrounding environment – Separate or adjacent or Combined goods inwards and outwards.
c) **Storage operating strategy** – Influence performance and Cost of storage system – increase in the throughput and utilization of rooms ad floor space.
d) **Occupancy strategies** – Fixed storage locations, Free storage locations, Zoning. [12]

2.2.7 Material handling equipment's

In a manufacturing, distribution, or warehouse scenario, a variety of tools, machines, and vehicles are referred to as material handling equipment and are used for the movement, storage, control, and protection of materials and goods. Typical instances of material handling machinery include:

<u>Material Transport equipment</u>

1. Industrial Vehicles

a) Walking

- Hand truck and Hand cart
- Pallet jack
- Walkie stale

Figure 4 Pallet jack [13]

b) Riding

- Pallet truck
- Platform truck
- Tractor trailer
- Counter balanced Lift truck
- Straddle carrier
- Mobile yard crane

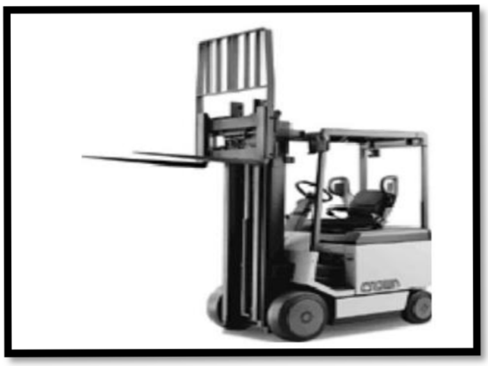


Figure 5 Counter balance lift truck [13]

c) Automated
    - Automated Guided vehicles – Unit load carriers, Towing vehicle, small load carrier, Assembly vehicle, Storage vehicle.
    - Automated Electrified Monorail
    - Assorting transfer vehicle

d) Monorails Hoists and Cranes
    - Monorails
    - Hoists
    - Cranes – Jib crane, Bridge crane, Gantry crane, Tower crane, Stacker crane[13]

This report focuses on material handling systems due to its relevance to logistic system design. Logistics primarily involves the transportation of materials, making the handling of loading, unloading, and movement of items an essential activity. This report highlights the predominant use of specific types of electric forklifts and pallet jacks within the company, as they play a crucial role in transportation and loading operations. Within the industry, material handling equipment is commonly employed for pallet and heater movements. This study examines various general items that are commonly utilized for these purposes.

2.2.8 Trucks

Trucks are "motor vehicles with at least four wheels, used for the carriage of goods," according to the European categorization system. They weigh in at more than 3.5 tonnes. The majority of the items we need on a daily basis—fresh food from the grocery store or corner store, newspapers and periodicals, electronics and appliances, apparel, and so forth—rely on trucks at some stage in the distribution process. In modern economies, 85% of road freight tonnage is transported over routes with a practical travel time of 150 kilometres or less. Less than 1% is transported more than 1,000 kilometres. 2.4 million people work in the road freight transportation industry. [14]

Types of trucks

- The dumper trucks (It is the heavy-duty vehicle that is frequently utilized in the road and public works industries)
- The semi-trailer vehicle
- The tanker trucks
- The ampliroll truck

- The refrigerated truck
- The flatbed trucks.
- The tautliner truck

Among the most popular kinds of trailers and semi-trailers. The main advantages of "tilts" are their portability, capacity, variety, and lightweight. Rear, side and top loading are all available, and the frame can be disassembled if necessary.[15]

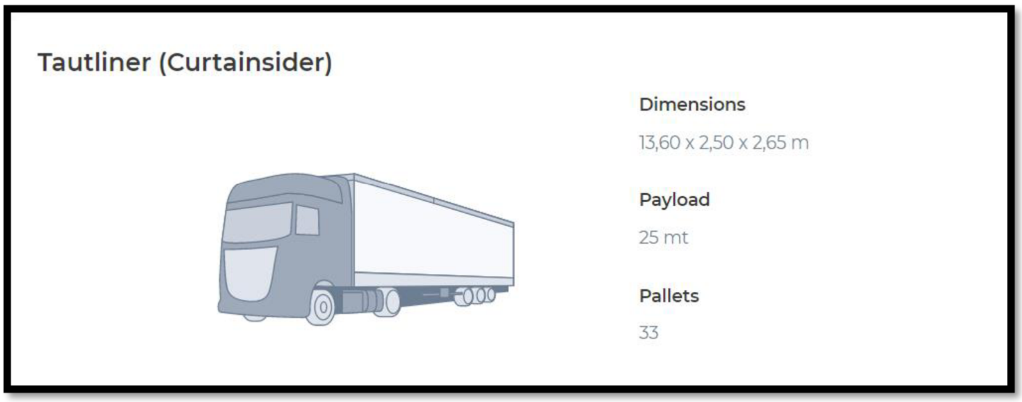


Figure 6 Curtainsider truck [15]

The company uses a really large truck that is classified as a tautliner. With solid rear doors, these are comparable to Euroliners but lack side gates and sideboards. With its all-around versatility, the Tautliner can load and unload from the back, sides, and overhead.[15]

2.3 Vehicle Routing Problem (VRP)

One of the most researched combinatorial optimization problems, the Vehicle Routing Problem (VRP) is concerned with the best design of routes to be used by a fleet of vehicles in order to serve a group of customers. However, if there are no other restrictions, assigning just one vehicle to visit every place and figuring out its shortest path is the best course of action. This issue is quite similar to the TSP issue. Minimizing the length of the longest single route taken by all vehicles is a more effective technique to determine optimal routes. If the objective is to fulfil all deliveries as quickly as possible, then this definition is appropriate. [16]

2.3.1 Capacity constrains

- The capacitated vehicle routing problem (CVRP) is a VRP in which vehicles with a constrained carrying capacity must pick up or deliver things at multiple places.
- The vehicles have a maximum carrying capacity, while the items have a quantity, such as weight or volume.
- The challenge is to pick up or transport the products as cheaply as possible without going over the vehicle's carrying limit.
- Each vehicle may be capable of carrying a maximum amount of multiple different types of cargo in more complicated CVRPs. For instance, a fuel delivery vehicle may transport several fuel kinds utilizing a number of tanks with various capacity. [17]

2.3.2 Capacity equations

The capacity equation is a formula used to determine a system's or process's maximum output or productivity. The equation differs according on the kind of system or process being studied, but it may generally be written as follows[18]:

Capacity = (Total available time) x (Efficiency or Utilization) x (Effective resource capacity)

2.3.3 VRP with time window

- Scheduling visits to clients who are only available within specified time slots is a common vehicle routing difficulty. The term "vehicle routing problems with time windows" refers to these issues. (VRPTWs).
- Deliveries to supermarkets, bank and postal deliveries, industrial waste collection, school bus routing, security patrol service, and distribution of urban newspapers are all significant VRPTW applications.[16]

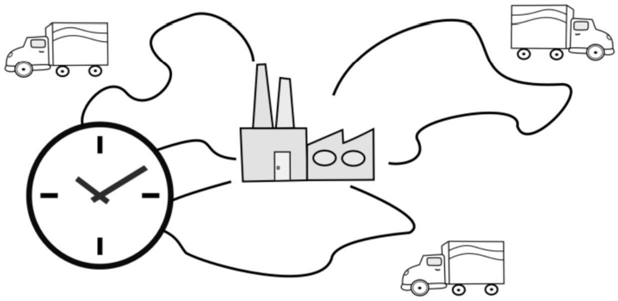


Figure 7 VRP with time window [19]

2.3.4 Resource constrains

- We have been focusing on routing issues with restrictions that are relevant during vehicle travel up until this point. Then, we demonstrate a VRPTW that is similarly subject to restrictions at the depot, requiring that all vehicles be loaded before they leave and unloaded when they return.
- Only two loading docks are provided, so no more than two cars can be loaded or unloaded simultaneously. Due to the need to wait for others to be loaded, some vehicles' departure from the depot is delayed. The challenge is to identify the VRPTW's ideal vehicle routes while also taking into account the depot's loading and unloading restrictions. [16]

2.3.5 Challenges in prior routing

- Only a portion of the customers of many delivery services need a pickup or delivery every day. When creating daily schedules for customers who do need visits, information may not be accessible far enough in advance or it may be too expensive to purchase the necessary computer capacity.
- For years, businesses have relied on a priori approaches to assist them get over these obstacles. A route that specifies an ordering of all potential clients that a specific driver may need to visit is known as an a priori, or pre-planned, route.
- The route's customers who have not received a delivery may then be skipped by the driver. In the package express sector, a priori routes are frequently utilized to order the numerous potential stops.

- The problem is known as the probabilistic traveling salesman problem with deadlines in the case of a priori routing.
- A growing number of delivery organizations are dealing with a more challenging routing issue as a result of just-in-time business strategies. [16]

2.3.6 Truck Scheduling and requests

A fleet of uniform trucks that must be routed and scheduled within strict time that fulfils the transportation needs.

- Containers are considered transportation resources and are made available to customers for the transportation of freight.
- The latter necessitates empty container movement, which is also covered in this context.
- The carrier's goal is to reduce overall travel expenses, which are inversely proportional to the combined operational time of all vehicles in use.
- Thus, the total operating time is made up of the time spent traveling overall as well as the time spent waiting at the terminal and at customer locations.
- Furthermore, we consider the truck fleet's size to be set. Based on an estimation of the range between the highest and lowest demand, a carrier normally invests in a moderate fleet size.
- However, because of the high degree of uncertainty in the demand prediction, the carrier either charters trucks or subcontracts transportation requests to outside carriers at times of peak demand.
- Each transportation request specifies an origin, a destination, and additional tasks that are stated below in the chronological sequence in which they must be completed. The activities are divided into activities for fully loaded containers (FA), empty containers (FA), and origin (OA) activities. (EA). [20]

Types of requests

➢ **Inbound Full Request** (Terminal Origin, Receiver Customer Destination):

- OA: A truck is dispatched to the designated terminal to take up the fully loaded container.
- FA: The container is handed off to the designated receiver client.

- DA: The container is delivered to the recipient client, who unpacks it, and then the remaining empty container is picked up.
- EA: Either a depot or a shipper customer or terminal in need of an empty container for freight transportation will receive the empty container.

➢ **Inbound empty request** (receiver terminal origin, unknown destination):

- OA: A truck is dispatched to the designated terminal to pick up the empty container.
- EA: Either a depot or a shipper client or terminal in need of an empty container for freight transit receives the container.

➢ **Outbound Complete Request** (Customer Shipper Origin, Terminal Destination):

- EA: A truck will transport an empty container to the designated shipper client, either from a depot or from a receiver customer or terminal.
- OA: The empty container is delivered to the shipper client, where it is filled with cargo, and then the completely loaded container is picked up.
- FA: The container is delivered to the designated terminal when it is fully loaded.
- DA: A terminal employee delivers the shipment.

➢ **Outbound Empty Request** (Origin: Unknown, Destination: Unknown)

- EA: A truck is used to deliver an empty container from a depot or a receiver terminal to the designated terminal.
- DA: A terminal employee delivers the shipment. [20]

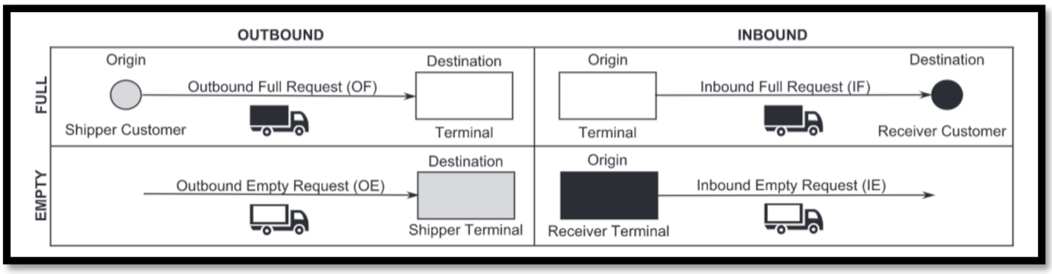


Figure 8 Truck scheduling requests [20]

Example of a transportation request

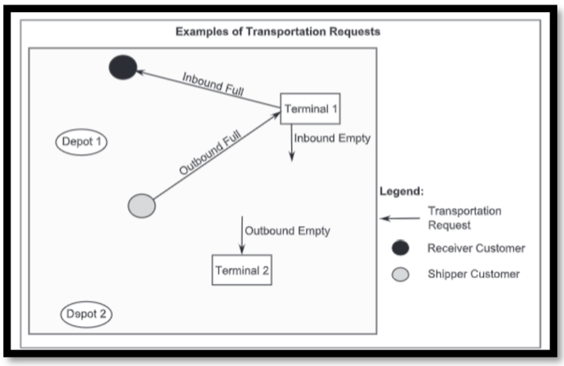


Figure 9 Example of transportation request [20]

To fulfil a variety of transportation requirements that are subject to origin and destination time frames, trucks must be routed and scheduled. Additionally, empty containers are allotted to clients and terminals for the movement of freight and are thought of as transportation resources. The goal is to reduce the overall amount of time that trucks are operated.

2.4 Alternate Transport systems

As we can see, trucks are conducting the logistical operation in Drazice, but it is always essential to consider the alternatives because doing so will help us understand the cost of transportation and how to carry out logistics for transportation more effectively. Alternative transportation methods can be employed inside and outside industries to boost production and efficiency. Here are a few instances:

- Conveyor belts are a typical type of transport used in companies to carry goods and materials from one place to another. They are frequently used for automated production processes and can be tailored to meet various plant layouts.
- Automated guided vehicles are autonomous vehicles that can move supplies and goods across a factory floor with no assistance from a human. They are perfect for repetitive activities since they can be programmed to take specified paths.
- Drones: Small goods can be moved around a production floor using drones. They are especially helpful in huge warehouses or factories with high ceilings where human workers could find it challenging to access.

- Monorail systems: These transportation methods move goods and materials from one place to another by using a single rail track. They can be used to transport large objects over long distances, and they are especially practical in factories with constrained floor space.
- Vertical conveyors: In a manufacturing, vertical conveyors are used to transport goods and materials between levels. They are frequently used in factories with numerous floors and can be tailored to meet special requirements.

In our situation, the goal is to move supplies from the production to the warehouse, which is located approximately 250 meters away. Consequently, we might think of rail and AGV transportation as the alternatives to trucks.

2.4.1 Railing transport of pallets

- Palletized items are transported inside a manufacturing or distribution facility using rail systems. This kind of transportation can be useful in sectors like the consumer goods, pharmaceutical, and automobile industries where huge volumes of products need to be moved swiftly and effectively.
- Pallets are often loaded onto rail trains and dragged or pushed along rails to their final destination inside the facility. Rail systems can be either automated, in which case a computer system directs the movement of the pallets, or manually operated, in which case employees direct the motion of the rail cars.
- Pallet transportation by rail has the potential to be quicker and more effective than alternative intra-facility transportation methods like forklifts or conveyor belts. Rail systems can transport heavier loads all at once, requiring fewer journeys to move the same amount of cargo. Additionally, pallets may be moved between different levels of a facility using rail systems, which is advantageous in sectors where space is at a premium.
- Another benefit of shipping pallets by rail is that it may be safer than other intra-facility movement methods. Because rail systems are frequently enclosed, there is a lower chance of accidents involving people or machinery. Additionally, pallets can be moved swiftly and easily on rail systems, lowering the possibility of product damage. [21]

Figure 10 Rail transport of containers [22]

2.4.2 Automated Guided Vehicle (AGV)

- It is a particular class of mobile robot that does not require a human operator to transport products or materials inside a manufacturing or distribution facility. Sensors and software that are part of AGVs let them to move around a facility, avoid obstacles, and carry out activities like picking up and delivering products.
- AGVs can be used to automate a range of material handling duties, including transferring finished products to storage facilities, moving raw materials to production lines, and delivering goods to shipping regions. They can be programmed to follow particular patterns or routes inside a building and can be built to handle a variety of loads, from small boxes to big pallets.
- AGVs normally run on batteries, which are rechargeable when not in use. They can be set up to run continuously, which will boost a facility's productivity and efficiency.
- AGV use has the potential to save time and money by reducing the requirement for human labour in material handling operations. They may be built to prevent collisions with other pieces of equipment or personnel, which can enhance facility safety.
- In general, material handling operations can be automated with the use of AGVs in a number of industries, including manufacturing, warehousing, and distribution. They may contribute to a facility's increased safety, lower expenses, and increased efficiency. [23]

Figure 11 Industrial AGV [24]

3 DZ Dražice Logistic system optimization

Drazice is the world's top producer of premium water heaters, and their goods are sold in more than 60 nations. The business is renowned for its cutting-edge technology and original designs, and they are dedicated to offering clients effective and dependable items that satisfy their needs. Electric storage water heaters, instant water heaters, and heat pumps are just a few of the several types of water heaters that Drazice manufactures. Customers in the residential and commercial sectors can choose from a range of sizes and capacities for their electric storage water heaters.

Drazice manufactures its water heaters in cutting-edge facilities that are up to date with technology. The production methods used by the company are intended to be both effective and environmentally responsible. The objectives of this project are to design a logistic system focusing on transporting finished products, assess the adequacy of available trucks for material movement, create a transport schedule, and analyse alternatives for transporting materials from Lustenice to a nearby warehouse (approximately 250m distance).

The industry operates on a push system, producing based on forecasts. Information regarding production is communicated to suppliers for raw material supply, and workers receive the production plan on the day of operation, indicating the information communication time. While individual activity timings can be determined, the total production time (PLT) remains unknown due to the extensive product range and variants. Expedition times for Drazice and Lustenice are known, emphasizing the need for optimized outer logistics. Inefficient truck utilization and unused space result in inefficiencies and potential waste. To address this, a new loading algorithm is developed, maximizing timing, labour, and space utilization. A current schedule is created, identifying and removing unwanted activities, leading to an optimized schedule. Loading arrangement utilization is calculated, ensuring effective use of available trucks for efficient task execution. The thesis allows for future improvements based on production enhancements, facilitating ongoing upgrades.

3.1 Analysis of production base

Analysis of a production base entails the process of looking at and assessing the different elements of a manufacturing facility. Such a study seeks to pinpoint areas where enhancements might be made to boost output, cut expenses, and improve overall performance. This involves looking into each stage of the production process, from the procurement of raw materials through the assembly of completed products, Understanding the complete production process makes it feasible to spot areas for improvement in waste reduction, quality enhancement, and output

Points to note

- There are two production areas Drazice and Lustenice and a Warehouse.
- Two production lines are located in Drazice, and one is located in Lustenice.
- Heaters are produced both in Drazice and Lustenice that are transported by 2 trucks to the warehouse.
- There is a gas station near warehouse that belongs to Drazice.
- Warehouse have 2 loading/Unloading stations.
- Pallets are manufactured and repaired near the warehouse.
- Production is based on forecast.
- Every morning, truck leaves from Drazice and returns there at night.

3.1.1 Production shift and transport Shift of Drazice

Similar to how what we produce is an essential aspect. Another important aspect that needs to be considered is when we produce. Production shift is a key idea in production base analysis, which is used to assess the productivity and efficiency of a production facility or manufacturing plant. The term "production shift" describes how much can be produced by a manufacturing facility or production line in a specific amount of time.[25]

The following kinds of production shift analysis can help to better understand how well a manufacturing facility is performing:

- Production scheduling and capacity planning can both benefit from using production shifts to identify the maximum output potential of a production line or factory.
- Production shifts can also be used to assess a factory's effectiveness in utilizing its labour force. Manufacturers can discover areas where labour productivity can be increased and put steps in place to optimize their personnel by examining the production per employee each shift.

Table 1 Production schedule timings [Source: Drazice]

Shift	1	2	3
Shift timing	06:00 - 14:00	14:00 - 22:00	22:00 - 06:00
Break 1	08:00 - 08:05	16:00 - 16:05	00:00 - 00:05
Break 2	10:15 - 10:45	18:15 - 18:45	02:15 - 02:45
Break 3	12:10 - 12:15	20:10 - 20:15	04:10 - 04:15
Break 4	13:50 - 14:00	21:50 - 22:00	05:50 - 06:00

The company uses three shifts for production; yet, material transportation only uses two shifts.

Shift	1	2
Shift timing	05:00 - 14:00	14:00 - 22:00
Break 1	08:00 - 08:05	16:00 - 16:05
Break 2	10:15 - 10:45	18:15 - 18:45
Break 3	12:10 - 12:15	20:10 - 20:15
Break 4	13:50 - 14:00	21:50 - 22:00

The schedule that created should fit into these shifts and their break times.

3.1.2 ABC analysis

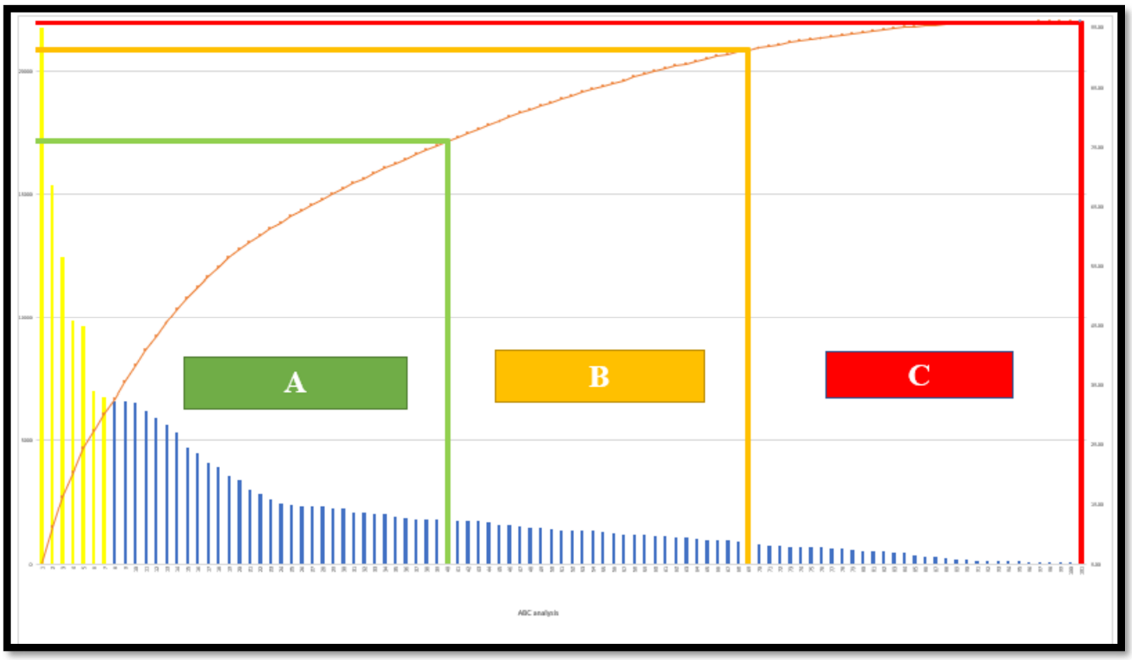
Three categories—A, B, and C—are used to categorize the products in this investigation. The best-selling products fall into Group A, whereas the worst-selling ones fall into Category C. A firm can better understand which goods are generating the most money and where to focus their efforts for process improvements by evaluating the sales data of each product and finding the most sold product.

- The ABC analysis can also be used to find any inefficiencies in the product transportation logistics system. This can include the amount of time and money needed for transportation as well as the possibility of delays or product damage while in transit. [4]
- The presented analysis is a sample of ABC.

- The products with the maximum sales and profit are given in table 3. The complete table showing all the product details is given in the attachment 1.

Table 2 Selected products from ABC [Source: Own]

Products	Total products	Percentage
NAD 100 v1, NAD 50 v1	21755	8.94
OKCE 125	15359	6.31
OKCE 80	12425	5.11
OKC 300 NTR/HP	9882	4.06
OKCE 160	9667	3.97



Graph 1 ABC Analysis [Source: Own]

These selected products are highlighted in yellow colour in the Graph 1. The process from the start to the end of these products are further analysed and listed in the next process diagram. These types and variants have been operating effectively in the market, and we can draw the conclusion that their production and logistics need to be examined for improvements and optimization.

4 Information and material flow analysis

Analysing the flow of information and materials entails identifying the major inputs, outputs, and activities that make up the logistics system as well as the system's boundaries (such as the geographical area served.

- Creating a visual representation of the movement of information and materials within the logistics system by mapping out the flow of both. A range of tools, including flowcharts, value stream maps, and process maps, can be used for this.
- Gathering information on transportation expenses, inventory levels, or other pertinent variables.
- Analysing information flow entails looking at how the supply chain exchanges information and makes decisions, including how information systems and communication networks are used.
- Analysing material flow entails looking at the handling, storage, and transportation of items as they move through the supply chain. This study can assist in pinpointing the locations where supplies are being lost, damaged, or held up, causing delays or higher expenses.

We can acquire a thorough understanding of the complete logistic system and make data-driven decisions to optimize performance and cut costs by combining information and material flow analyses. [11]

4.1 Plant layout with spaghetti diagram

This is the layout of Drazice production line 1. The movement of materials and storage of materials are all marked and listed. The production line has 8 work stations and 5 storage areas. They are

- S1 – The outer storage area, where raw materials and semifinished products are unloaded and temporarily stored.
- S2 – The second storage area where metal sheets are stored.
- W1 – workstation where welding operation is performed, both manual and machine welding operations are done.
- W2 - Testing area where the welded boilers are tested for leakages.

- W3 – Sandblasting operation is done here.
- W4 – Enamelling operation is done here.
- W5 – Some variants undergo furnace in this workstation and some variants won't undergo furnace process.
- S3 – Cooling area where hot boilers are set to cool
- S4 – Delay area where Boilers are stored for next process
- S4 – Outer casing metal sheet and boilers storage
- W6 – Outer body rolling
- W7 – Outer body assembly
- W8 – Final assembly
- Expedition – Products are packed in pallets for transport.

The spaghetti diagram demonstrates the movement of elements within the layout framework from beginning to conclusion, clearly outlining the process that is taking place and also revealing its order.

- The spaghetti diagram is drawn with access points Where the green colour is the exit point and red colour is the entry point.
- The purple colour denotes that the entry and exit points are in the same place.
- Inner boiler preparation is mapped in yellow colour line and outer body raw material and semi-finished product movement is given in green colour line.
- The finally assembling part movement is given in red colour line.

The layout with the spaghetti diagram is given in figure 15.

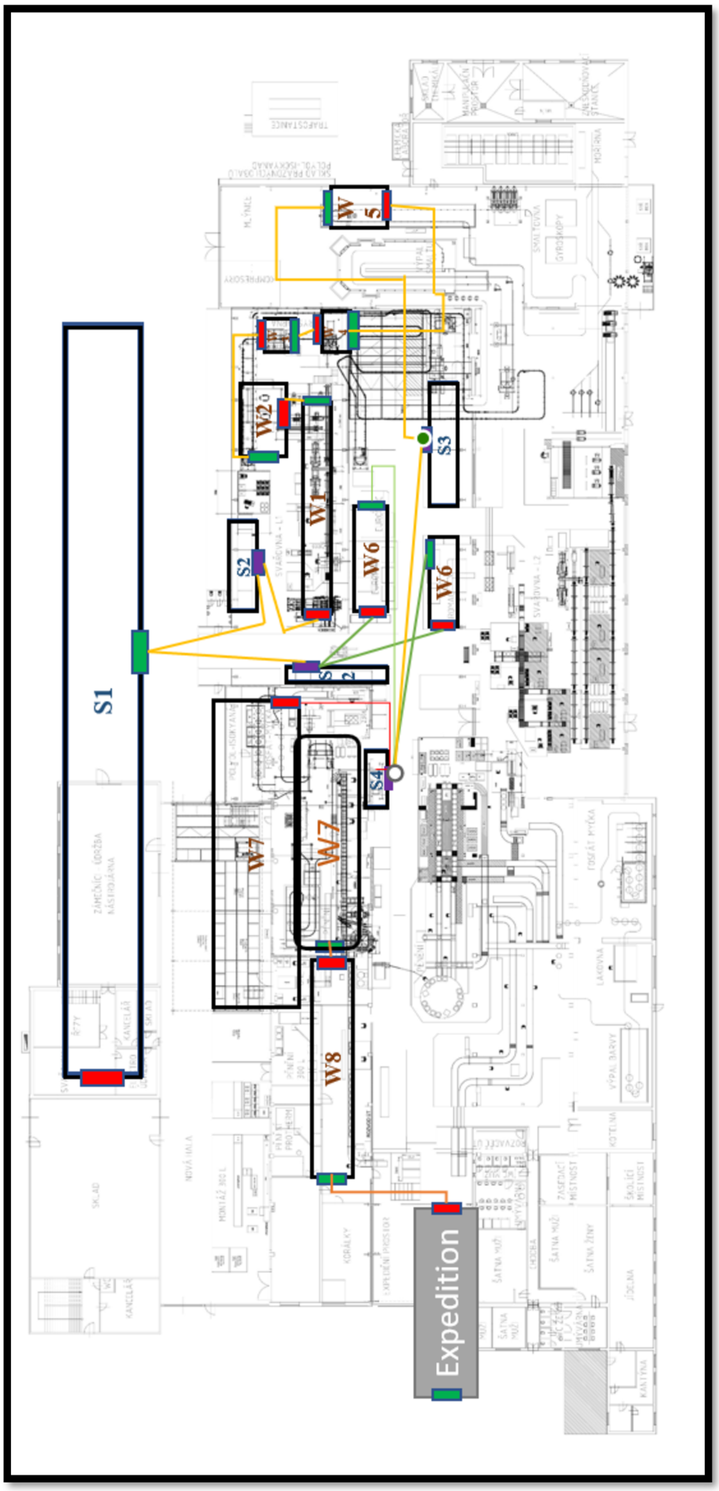


Figure 12 Layout with spaghetti diagram

4.2 Process diagram

The steps that are carried out from planning to delivery are shown in the process diagram that is given in 3 parts in figure 13,14,15. This is done so that we can better understand the chronological order of events.

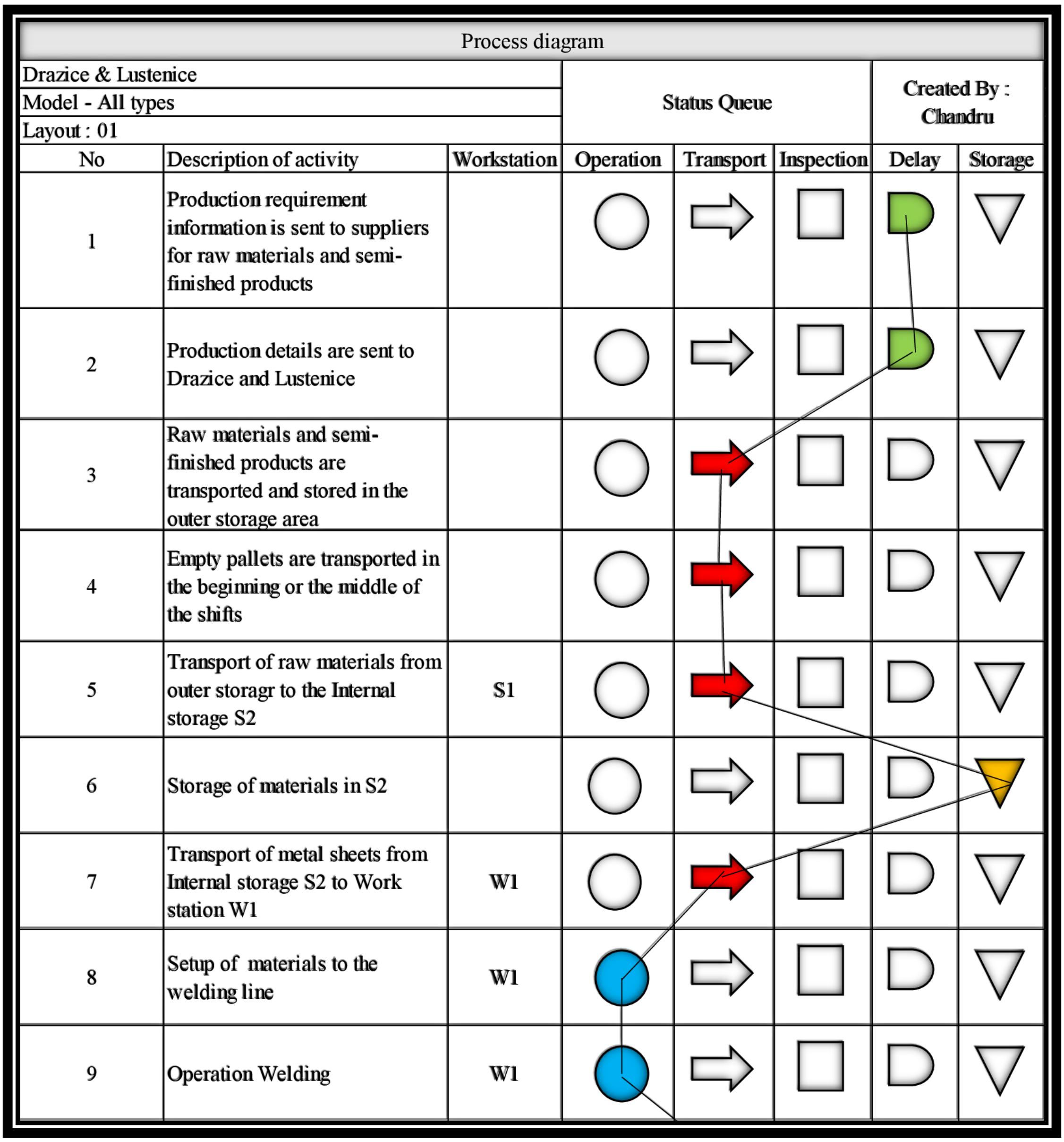


Figure 13 Manufacturing and Logistic process diagram part 1 [Source: Own]

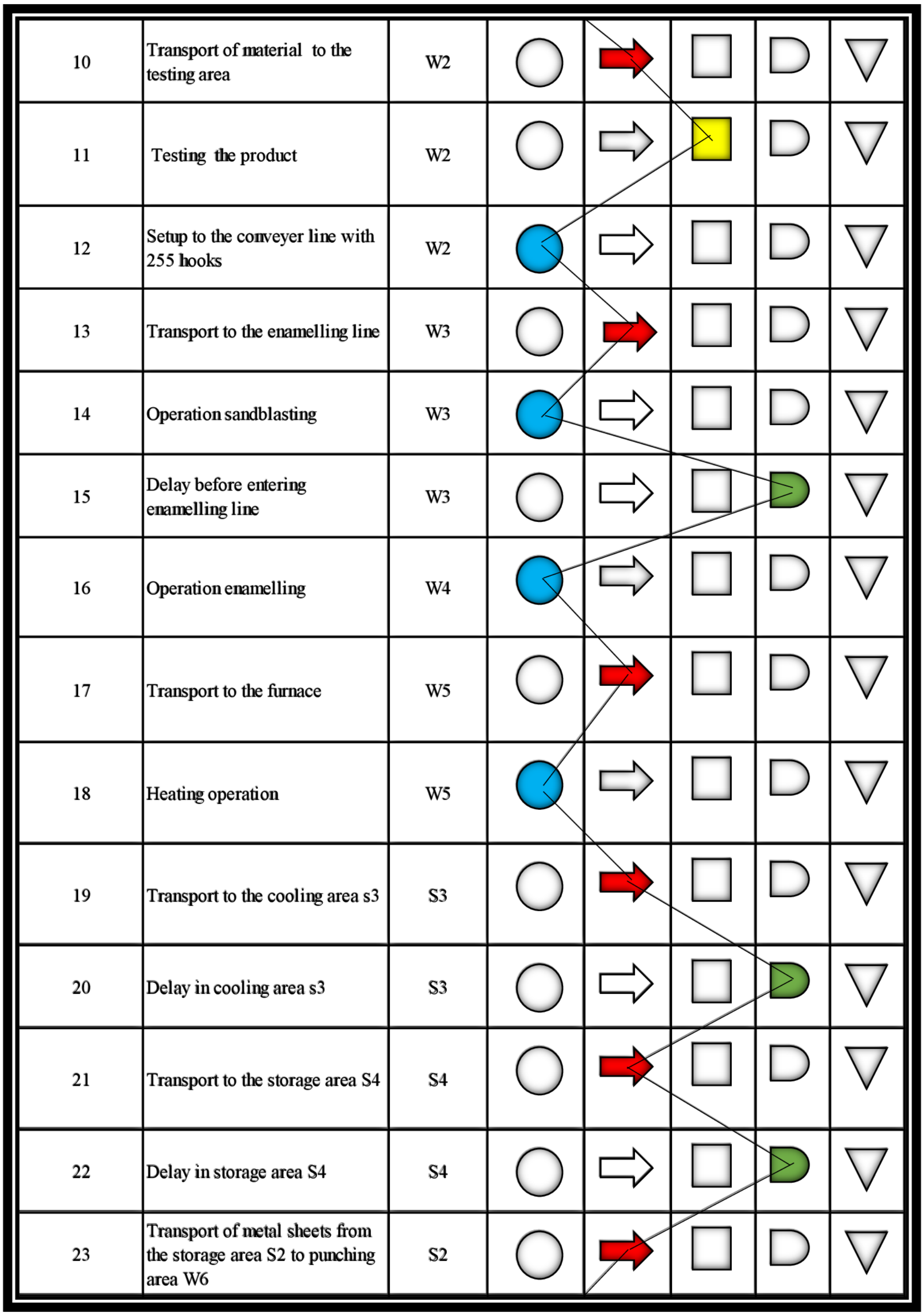


Figure 14 Manufacturing and Logistic process diagram part 2 [Source: Own]

24	Punching operation W6	W6
25	Transport of material from the W6 to the Internal storage S6	W6
26	Transport of materials from the storage area S4 to the storage area S5	S5
27	Transport of materials from S5 to outer casing assembly W7	S5
28	Setup of materials to for outer casing assembly	W7
29	Outer casing assembly operation	W7
30	Transport of assembled product to the final asembly W8	W7
31	Final assembly operation and testing	W8
32	Transport for expedition	D
33	Pallets with finished products are loaded in the trucks	D,L
34	Transportation of pallets from Drazice and Lustenice to the warehouse	W
35	Finished products are stored in the warehouse	W
36	Transport of product to stores and to the customers	

Figure 15 Manufacturing and Logistic process diagram part 3 [Source: Own]

Interpretation

- The lead time for the goods is the crucial point that needs to be made here. Given that different models and types of products are manufactured in Drazice using the same process, we did not mention it in the table above.
- Based on the model and its ability to be manufactured, the product lead time ranges from 14 to 21 hours.
- Since we don't know the PLT as there are huge variants, we have trouble at the expedition by not knowing the type of pallet that comes out form the expedition for loading in trucks.
- By knowing which items comes first we know, what type of pallet it will be packed in then, we can easily make a better loading that could possibly reduce the required number of transports.
- I would suggest the use a software-based system called MES, or Manufacturing Execution System, is used in manufacturing facilities to track and monitor the production process in real-time.
- This track of production can give us a lot of information that can be further used for smooth production and to find opportunities to improve.

4.3 Process information and material flow picture description

- This section was worked on to gain a clear grasp of the entire process, including the flow of information and materials for production as well as the operations for production and logistics.
- The flow of materials and information was mapped using the VSM model because it is simple to retain a lot of information in a single image.
- It should be noted that this is simply a model to show the flow of the process and not an actual Value Stream Map.
- The distinction between VA and NVA cannot be made in this picture since the product lead time and individual cycle times are not fixed. It is not a true value stream map, but merely a visual depiction of the flow of materials and information.
- The raw material transport information is sent to the suppliers on a weekly basis.
- The production units receive the production information on a daily basis.

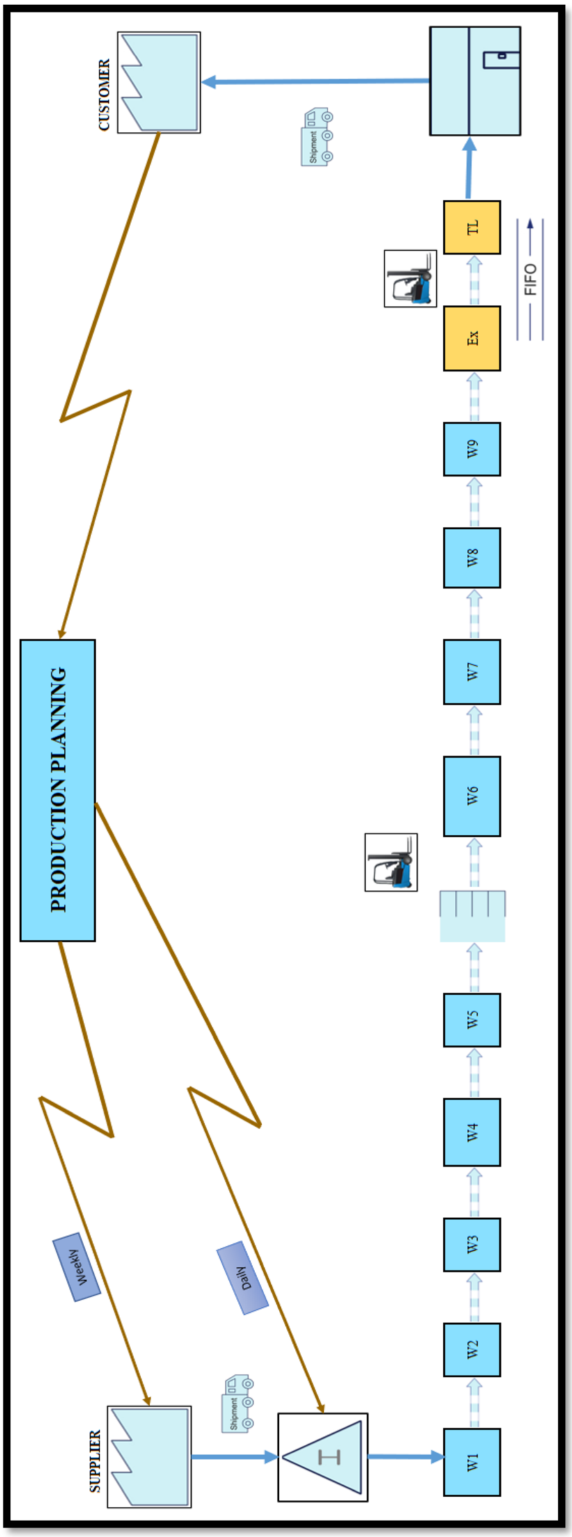


Figure 16 Model VSM Process picture description [Source: own]

- Our work here starts from the expedition. The expedition and loading are given in yellow colour in the Figure 17.

4.4 Transportation Matrix and Transportation route

The transportation matrix is a helpful tool for modelling and improving transportation networks, and it is crucial in many sectors that deal with logistics and transportation.

Transport distance matrix

Table 3 Transportation matrix [Source: Own]

Transport matrix	Warehouse	Drazice	Lustenice
Warehouse	0	7.75Km	250m
Drazice	7.75Km	0	7.55Km
Lustenice	450m	7.55Km	0

The paths that goods and commodities take as they move from one point to another are referred to as transportation routes in logistics. These routes may include the use of trucks among other types of transportation. In logistics management, selecting a transportation route is crucial since it affects the price, duration, and effectiveness of the transportation process.

Table 4 Transport routes [Source: Own]

D-W	
W-D	
L-W	
W-L	

D	Drazice
L	Lustenice
W	Warehouse

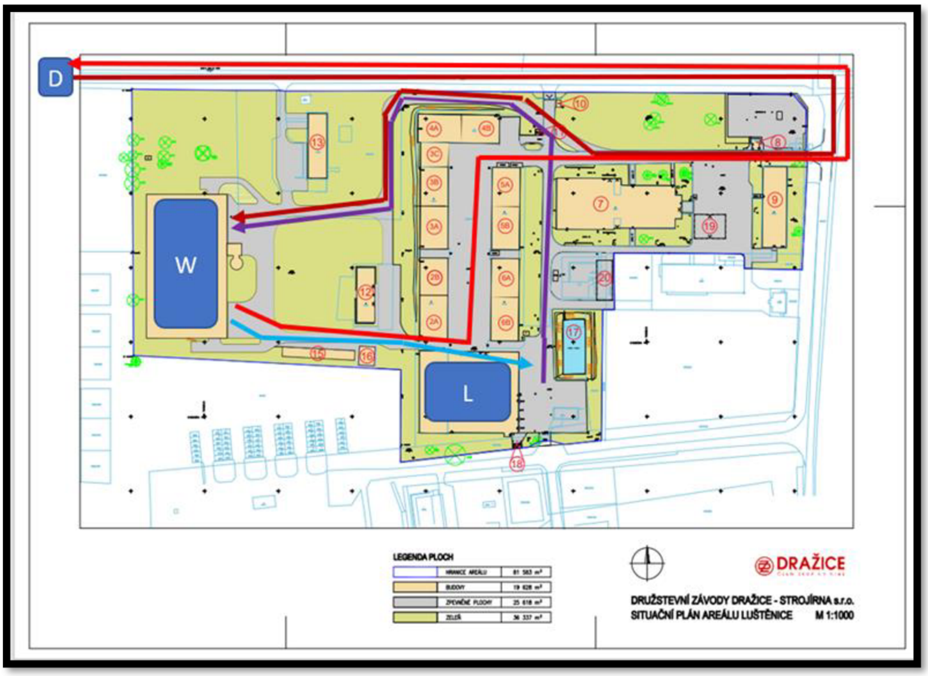


Figure 17 Transport route [Source: Drazice]

The routes between Drazice, Lustenice, and Warehouse, is studied and based on that, these most efficient routes with the shortest distances, allowing for low-cost transportation are selected and given in the Figure 17 and table 5 and their distances are given in the table 4.

5 Analysis of logistic operation of selected products

Data on the company's logistics operations, such as inventory levels, delivery times, and order accuracy are often collected as part of a logistic operation analysis. Then, in order to pinpoint areas that can be improved, this data is evaluated using a variety of tools and techniques, including day screening, selective timing, and chronometry.

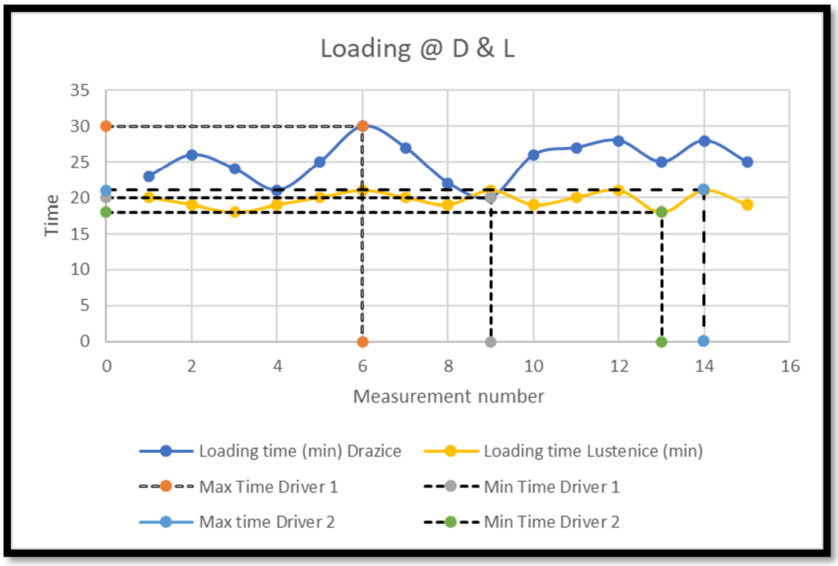
5.1 Average time distribution of each activity

When it comes to vehicle routing, loading, unloading, and transport times are the most important data to take into account. To determine the average time, it takes for all of these processes, we have collected 15 data from each driver. Each individual data supporting the graphs are given in attachment 2.

5.1.1 Loading Time at Drazice and Lustenice

The given graph 2 is the distribution of loading time of two drivers at Drazice and lustenice. From the graph 2 we can say that

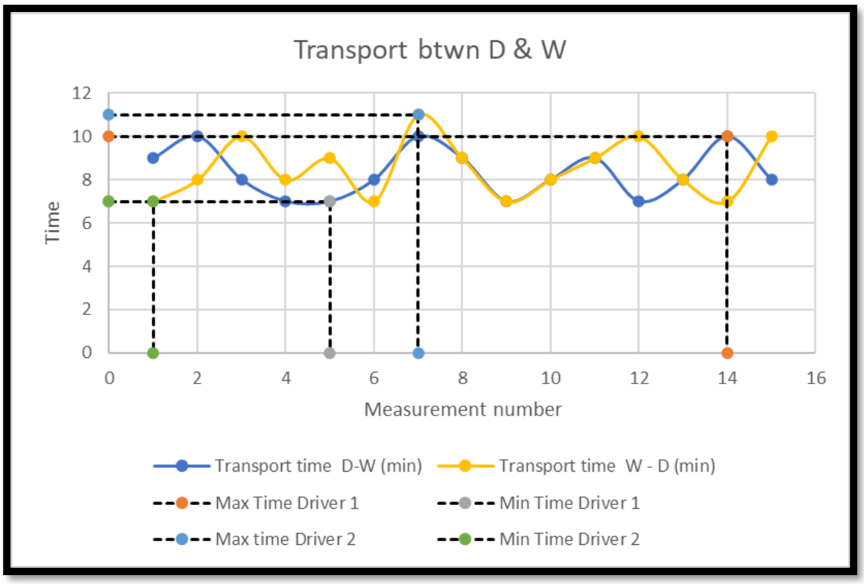
- The maximum time taken to load by driver A is 30 minutes and the minimum time taken to load is 20 minutes.
- The maximum time taken to load by the driver B is 21 minutes but the minimum time taken is 18 minutes.
- The variance in loading time of Driver A is 8 minutes while the Variance in loading time of driver B is 1.5 minutes.
- Hence the loading time varies from person to person and it is affected by various factors like production rate, work interest of driver, age, and so on.
- It is better to consider the maximum time taken for loading and design a loading pattern that utilizes the maximum space and works potentially in specified time limit.



Graph 2 Loading Time of drivers A and B [Source: Own]

5.1.2 Transport between Drazice and Warehouse

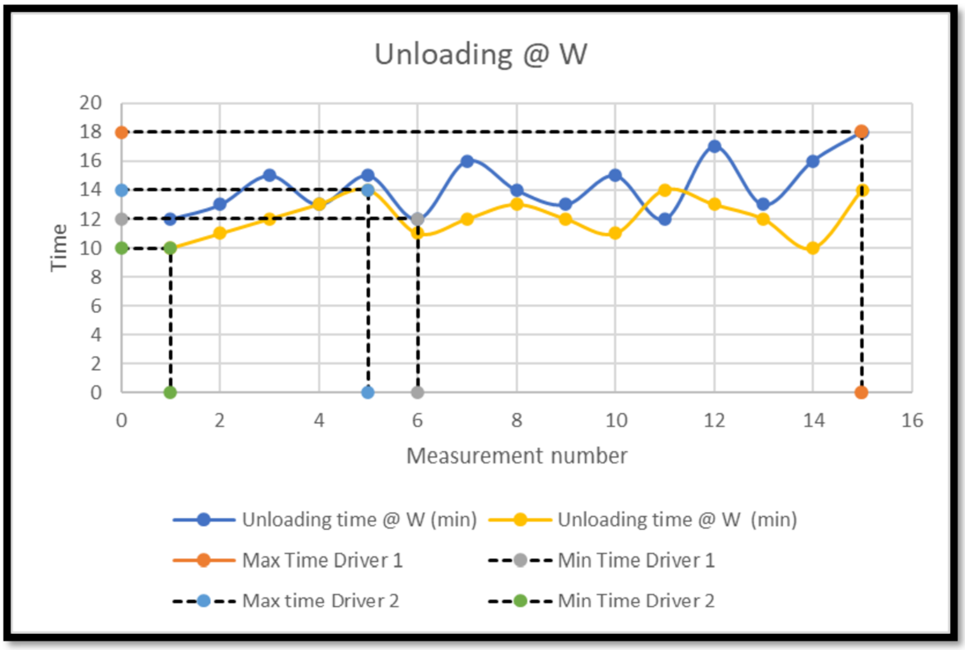
- From graph 3 we can say that, it takes between 7 to 11 minutes to transport goods from Drazice to the warehouse. Each driver has a 2-minute variance in time between them.
- In order to prevent fluctuations in transport times, we can analyse a variety of circumstances and establish the duration of transport that is relevant in most instances.



Graph 3 Transportation between D and W [Source: Own]

5.1.3 Unloading at Warehouse

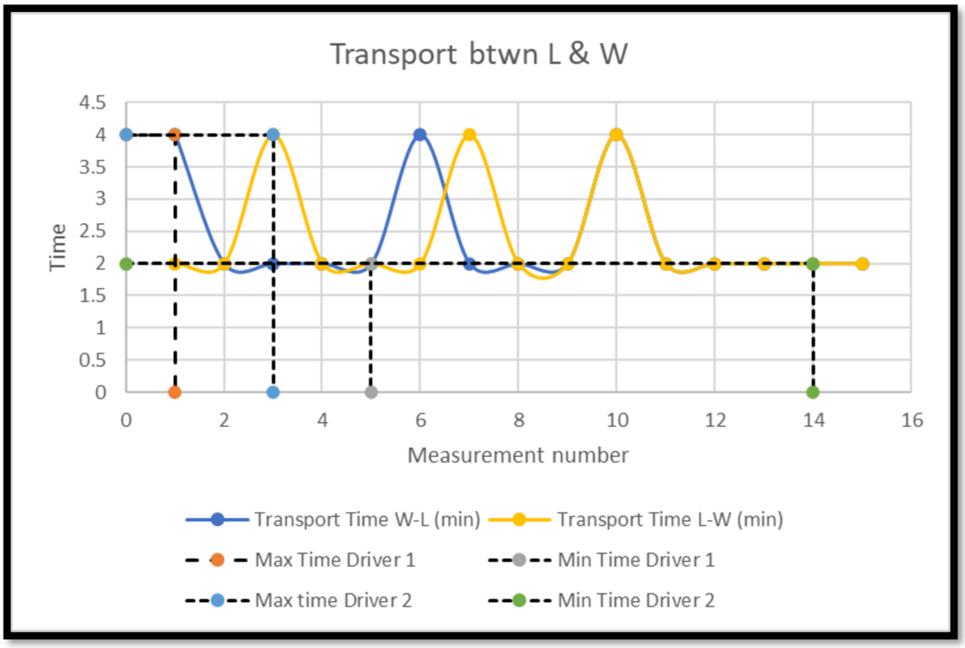
- The maximum and minimum unloading time each driver is given in graph 4.
- The variance in unloading times of driver A is 4 minutes and driver B is 2 minutes.
- The added information is, sometimes the unloading operation is done with the help of the warehouse workers as well.
- It is recommended to fix a time limit that matches the selected loading time limit.



Graph 4 Unloading time at warehouse [Source: Own]

5.1.4 Transport between Lustenice and Warehouse

- From the graph 5 we can see that both the drivers have shown same transport time between lustenice and warehouse. It is recommended to set a time.
- It is important to mention that the distance is 500m between Lustenice and warehouse that is short comparatively.
- The routes from lustenice to the warehouse and from the warehouse to lustenice are different.



Graph 5 Transportation between L & W [Source: Own]

5.2 Chronometry

Each phase of time of the process is examined to determine the VA and NVA timings, and the time spent on each activity is assigned to one of the two categories. After this study is finished, the business can pinpoint areas where NVA time can be cut back on and make adjustments to increase VA time.

5.2.1 Snapshot of the day

This snapshot of the day's activities aims to gather the time spent on each activity and determine which ones offer value and which ones don't.

The timing of each activity of a particular shift is collected. The details about the data are given in the table 6. For timing of individual activities, data's are given in attachment 3.

Table 5 Data driven date, time and place

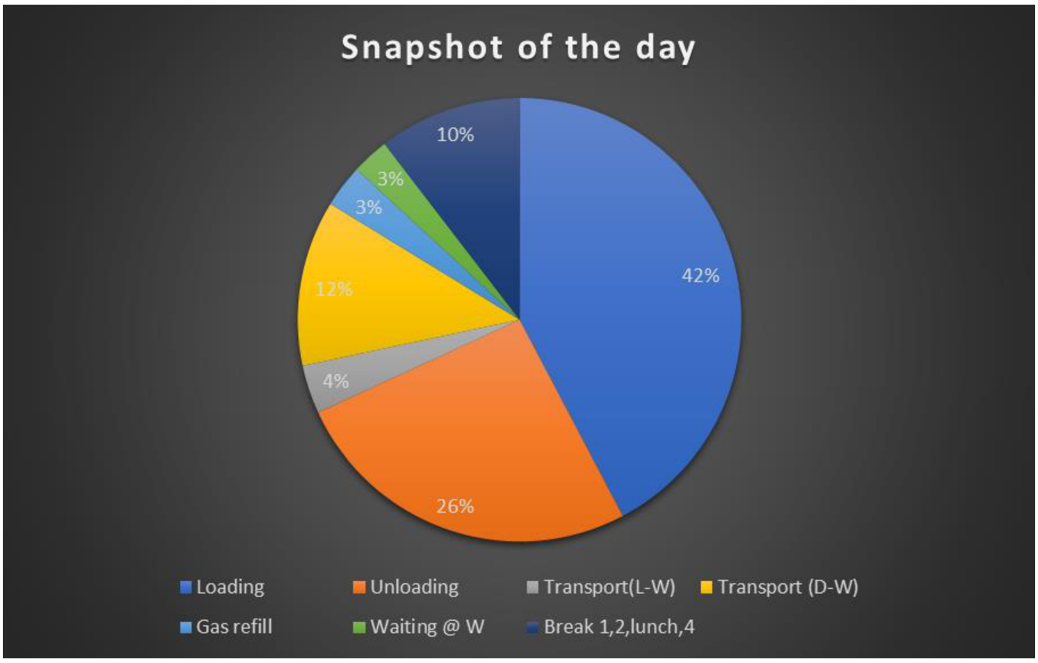
Workplace	D, L, W
Date (dd-mm-yy)	01-03-2023
shift	1
Observation time (hr:min:sec))	06:00:00
Beginning of observation time according to stop watch	00:00

The time collectively taken for each activity and name of each activity is given in the table 7.

Table 6 Duration of activities measured in a shift [Source: Own]

S.no	Symbol	Activity	Duration (mins)	Duration in Mins	Percentage
1	LD	Loading	03:23:00	203.00	42%
2	ULD	Unloading	02:04:00	124.00	26%
3	TLW	Transport(L-W)	00:17:00	17.00	4%
4	TDW	Transport (D-W)	00:58:00	58.00	12%
5	GAS	Gas refill	00:15:00	15.00	3%
6	D	Waiting @ W	00:13:00	13.00	3%
7	B1,2	Break 1 ,2 ,lunch, 4	00:50:00	50.00	10%

The pie chart of the snap shot of the day is given in graph 6



Graph 6 Snapshot of the day [Source: Own]

Interpretation

- Transportation is typically seen as a non-value-added procedure, but because we are addressing a logistical issue, our resulting conclusions have been adapted to our topic.
- Undoubtedly, the most time-consuming step in our logistical operation is loading and unloading, which takes up the most time overall.
- The next most time-consuming activity is the transportation.
- It is evident that the processes of refuelling, waiting, and taking breaks do not add value to the product or have an impact on logistics.
- From the above, we can consider Loading and unloading and transportation as value added activities and fuel refilling, waiting times and breaks as non-value-added activities.
- These non-value activities are still important for the process that cannot be neglected.

5.3 Current schedule

The plan or timeline for finishing chores and activities inside a single day is referred to as a current daily planner. This scheduler might be a daily creation or it might be a daily-followed recurrent routine. The complete schedule along with the Gantt charts of current schedule are given in attachment 4,5,6,7.

- Two trucks are being driven by four drivers. Drivers 1 and 2 work the morning shift, while Drivers 3 and 4 work the midday shift.
- It is possible to theoretically create the current truck schedule using the data from the previous study as well as information about the order of events that occurred throughout the day.
- This schedule has a lot of imbalance and unwanted activity
- Both the trucks head to the same place due to the lack of information or by purpose that creates an unwanted delay and un utilised wastage of energy.
- This schedule has to be optimized because it wastes resources and energy, yet there are still issues with efficient transportation.
- Rearranging delivery routes, changing delivery times, utilizing real-time tracking and monitoring technologies, and enhancing communication between drivers and dispatchers are just a few of the tactics that can be used to optimize the truck schedule.

- By putting these tactics into practice, you can make sure that deliveries are done on time, trucks are scheduled effectively, and unwelcome activities are kept to a minimum.
- Full schedule and its Gantt chart are given in the attachments.

The sample of current schedules of truck is given in figure 18 and truck 2 is given in figure 19.

Activity	Shift	Task allocated to	Daily activity	Time	Start	End	Task timing (min)
1	1	Driver 1	Loading @ D	06:00 - 06:20	6:00	06:20	20
2	1	Driver 1	Transport to W	06:20 - 06:28	06:20	06:28	8
3	1	Driver 1	Unloading @ W	06:28 - 06:40	06:28	06:40	12
4	1	Driver 1	Tansport to L	06:40 - 06:42	06:40	06:42	2
5	1	Driver 1	Loading @ L	06:42 - 07:03	06:42	07:03	21
6	1	Driver 1	Transport to W	07:03 - 07:05	07:03	07:05	2
7	1	Driver 1	Unloading @ W	07:05 - 07:20	07:05	07:20	15
8	1	Driver 1	Loading of pallets	07:20 - 07:35	07:20	07:35	15
9	1	Driver 1	Transport to D	07:35 - 07:45	07:35	07:45	10
10	1	Driver 1	Unloading pallets @ D	07:45 - 08:00	07:45	08:00	15
11	1	Driver 1	Break 1	08:00 - 08:05	08:00	08:05	5
12	1	Driver 1	Loading @ D	08:05 - 08:27	08:05	08:27	22
13	1	Driver 1	Transport to W	08:27 - 08:36	08:27	08:36	9
14	1	Driver 1	Unloading @ w	08:36 - 08:50	08:36	08:50	14
15	1	Driver 1	Transport to L	08:50 - 08:54	08:50	08:54	4
16	1	Driver 1	Delay @ L	08:54 - 09:05	08:54	09:05	11
17	1	Driver 1	Loading @ L	09:07 - 09:30	09:05	09:30	25
18	1	Driver 1	Transport to W	09:30 - 09:34	09:30	09:34	4
19	1	Driver 1	Unloading @ W	09:34 - 09:45	09:34	09:45	11
20	1	Driver 1	Tansport to D	09:47 - 09:55	09:45	09:55	10
21	1	Driver 1	Loading @ D	09:55 - 10:15	09:55	10:15	20
22	1	Driver 1	Lunch Break	10:15 - 10:45	10:15	10:45	30

Figure 18 Current schedule truck 1 sample [Source: Own]

Activity	Shift	Task allocated to	Daily activity	Time	IN	OUT	Task timing (min)
1	1	Driver 2	Loading @ D	06:00 - 06:20	06:00	06:20	20
2	1	Driver 2	Transport to W	06:20 - 06:28	06:20	06:28	8
3	1	Driver 2	Unloading @ W	06:28 - 06:40	06:28	06:40	12
4	1	Driver 2	Tansport to D	06:40 - 06:50	06:40	06:50	10
5	1	Driver 2	Loading @ D	06:50 - 07:12	06:50	07:12	22
6	1	Driver 2	Transport to W	07:11 - 07:20	07:12	07:20	8
7	1	Driver 2	Unloading @ W	07:20 - 07:35	07:20	07:35	15
8	1	Driver 2	Loading of pallets	07:35 - 07:50	07:35	07:50	15
9	1	Driver 2	Transport to L	07:50 - 07:52	07:50	07:52	2
10	1	Driver 2	Unloading pallets @ L	07:51 - 08:00	07:52	08:00	8
11	1	Driver 2	Break 1	08:00 - 08:05	08:00	08:05	5
12	1	Driver 2	Loading @ L	08:05 - 08:27	08:05	08:27	22
13	1	Driver 2	Transport to W	08:27 - 08:30	08:27	08:30	3
14	1	Driver 2	Unloading @ w	08:30 - 08:56	08:30	08:56	26
15	1	Driver 2	Transport to D	08:50 - 09:00	08:56	09:00	4
16	1	Driver 2	Delay @ D	09:00 - 09:05	09:00	09:05	5

Figure 19 Current schedule truck 2 Sample [Source: Own]

6 Design a Logistic model

You might be able to cut down on the amount of transportation required and related expenses by altering the way the vehicles are loaded. The number of trips needed to transport the same number of products can be decreased by increasing the number of items transported per trip by optimizing the truck loading arrangement. As a result, there may be a decrease in fuel consumption, pollutants, and vehicle wear and tear. Additionally, by lowering the necessary number of journeys, you can free up funds that could be invested in new equipment or used to boost productivity. In the end, improving the truck loading configuration can lead to significant cost savings and improved productivity for a company's logistics and transportation operations.

6.1 Loading information

It's crucial to know what we're going to load before deciding how to load. Let's look at the many sorts of pallets, their sizes, and the truck sizes.

6.1.1 Pallet types and dimensions

- There are two types of pallets, P4 and P2.
- P4 means pallets having 4 products and P2 means pallets having 2 products.

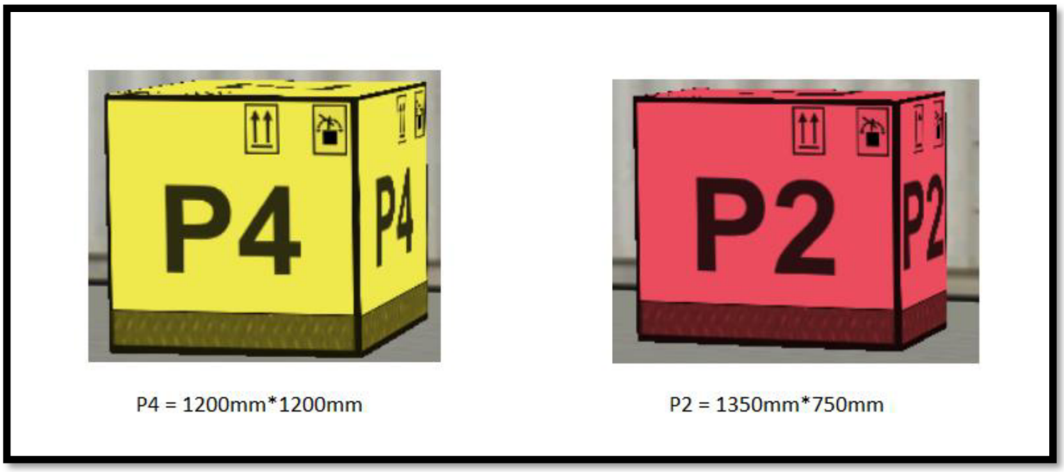


Figure 20 Pallet type and Dimensions [Source: Own]

- The height of the pallet differs depending upon the variants.
- Empty pallets are transported once or twice per shift

6.1.2 Truck space

There are two trucks. The containers in the trucks contains the pallets. The dimension of the container is L = 9.673m, B = 2.453m, H = 2.826m

- Pallets are loaded from the back of the container.
- Empty pallets are loaded from the sides of truck.
- So far only one layer of truck is loaded by pallets. The second layer is left empty that again results in increased number of transports and wastage of energy and resources.

Figure 21 Truck space [Source: Own]

6.2 Loading arrangement

The technique utilized to load pallets onto a vehicle for effective transportation is referred to as loading arrangement. The most effective use of the truck's space, the reduction of product damage risk, and overall efficiency can all be achieved with the right loading configuration. The size and weight of the items, the kind of truck being used, the route and destination of the shipment, as well as other criteria, must all be taken into account when choosing the ideal loading arrangement for pallets. P4 pallets can be loaded onto P2 pallets, but the reverse is not possible due to size and weight differences. Loading P2 pallets onto P4 pallets risks product damage if not properly arranged. Currently, only one layer is arranged in the company, but it is feasible to arrange a second layer. New loading arrangements have been implemented to meet limited transport requirements. While arranging two layers increases loading time slightly, it is manageable. However, as the number of pallets increases, loading time and subsequently unloading time also increase. Careful consideration of loading configurations is necessary to ensure efficient and safe transportation.

Overall, efficient transport and logistics depend greatly on the way that pallets are loaded. Businesses can save shipping costs and accelerate delivery times by carefully weighing the relevant aspects and employing efficient loading strategies.

For better understanding these details can help

Truck	Layer2	*2L*
	Layer1	*1L*

Truck	First half	Secong half
	H1	*H2*

P2	Pallets with 2 pcs
P4	Pallets with 4 Pcs

Figure 22 Truck description for arrangement [Source: Own]

The list of loading methods is given in table 8.

Table 7 Loading patterns

OL1	Old loading 1
OL2	Old loading 2
NL1	New loading 1
NL2	New loading 2
NL3	New loading 3

OL1 – 16 P4 pallets are arranged in layer 1 in the truck.

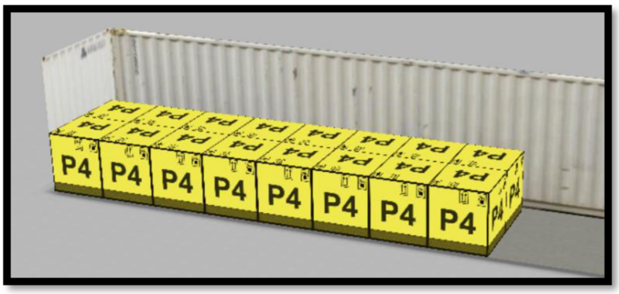


Figure 23 OL1 [Source: Own]

OL2 – 21 P2 pallets are arranged in 1 layer.

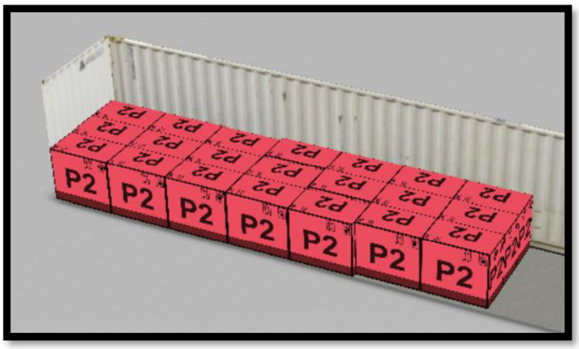


Figure 24 OL2 [Source: Own]

NL1 – 16 P4 pallets are loaded in 2 layers in the first half of the truck and 9 P2 are loaded in one layer in the second half off the truck.

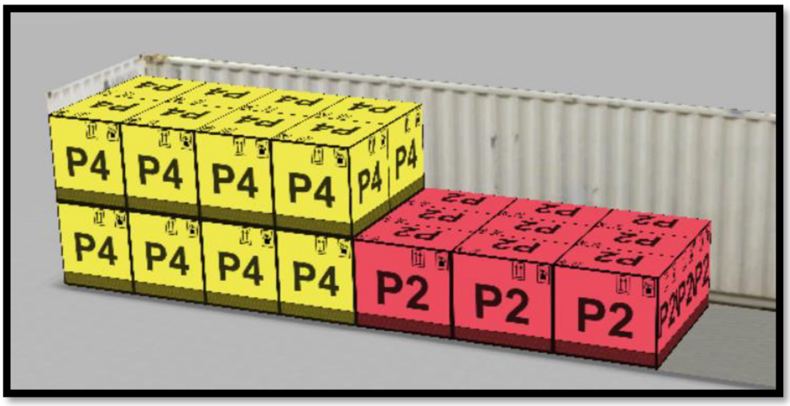


Figure 25 NL1 [Source: Own]

NL2 - 16 P4 pallets are loaded in 2 layers in the first half of the truck and 9 P2 are loaded in one layer in the second half off the truck and 8 P4 are loaded in the second layer of second half of the truck.

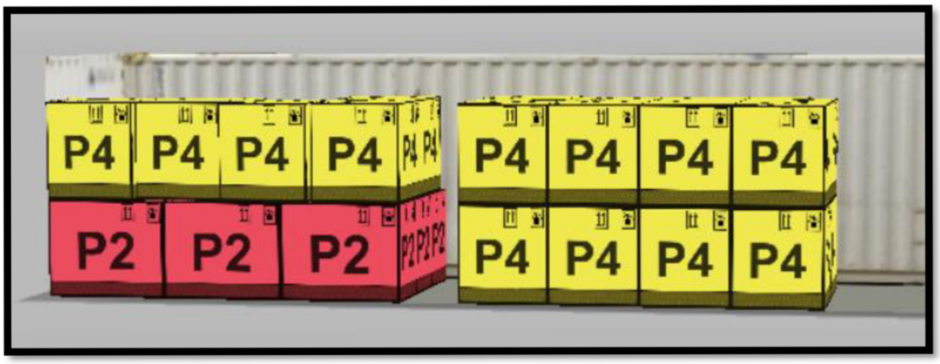


Figure 26 NL2 [Source: Own]

NL3 – 32 P4 are loaded in 2 layers of the trucks

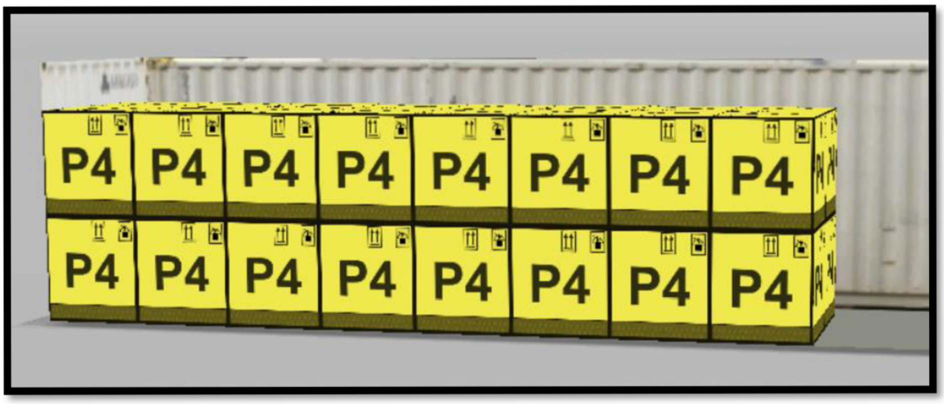


Figure 27 NL3 [Source: Own]

Due to significant changes made to the way vehicles are loaded, the new logistic model requires less transports than the previous model did.

6.3 Number of batches

In logistics, the number of batches refers to the number of shipments or transports required to move goods from one location to another. By optimizing the number of batches, businesses can reduce the number of transports required and save costs. This is due to the fact that higher batch sizes can aid boost productivity by reducing transportation requirements, increasing efficiency, and increasing overall efficiency. To balance batch size with other elements like transportation capacity, lead times, and inventory levels, though, is crucial. The transportation batch is given in table 8.

Table 8 Number of Transportation Batches [Source: Own]

Loading type	Number of P2 or P4 per batch		Number of pallets in layer 1		Number of pallets in layer 2		Total number of pallets	Recquired transportation capacity/shift	Total capacity for one transport	Total transport Batches required per shift	Number of batches
	P2	P4	H1	H2	H1	H2					
OL1		16	8*4	8*4			16	300	64	4.69	5
OL2	21		10*2	11*2			21	300	42	7.14	8
NL1	9	16	8*4	9*2	8*4		25	300	82	3.66	4
NL2	9	24	8*4	9*2	8*4	8*4	33	300	114	2.63	3
NL3		32	16*4		16*4		32	300	128	2.34	3

6.4 Algorithm for loading

The following pseudo algorithm loads the vehicle effectively by allocating the available pallets according to a set of criteria.

- It chooses the best placement strategy after taking into account the availability of various P4 and P2 pallet combinations.
- The method assigns pallets to various levels and the buffer to achieve optimal space use.
- It also manages situations in which the buffer is only halfway full, enabling wise loading choices.
- The vehicle may be loaded efficiently by using this method, which maximizes space use while upholding predetermined requirements and priorities.
- The maximum limit for the P2 is 21 and the maximum limit for the P4 is 32 pallets

The terms used in the algorithm is given in the figure 28 for better understanding,

P4	Pallets with 4 Pcs 1200*1200 (mm)
P2	Pallets with 2 Pcs 1350*750 (mm)
R	Row
C	Column
1L	Layer 1
2L	Layer 2
H1	First half of the truck
H2	Second half of the truck
m	Number of P4
n	Number of P2

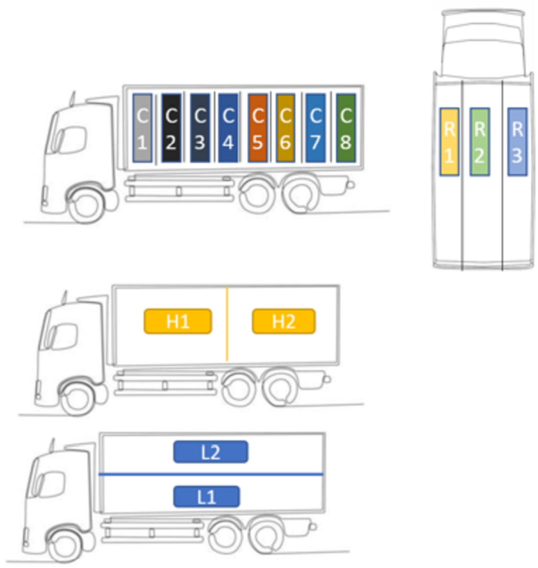


Figure 28 Algorithmic loading description [Source: Own]

Algorithm for loading:

WHILE truck is not full:
IF mP4 is available AND nP2 is not available:
Repeat Until *2L (2R, m/4C)* is filled, (C<=8):
Load mP4
ELSE IF nP2 is available AND mP4 is not available:
Repeat **Until** *1L (3R, n/3C)* is filled, (C<=7):
Load nP2
ELSE IF mP4 > nP2:
IF mP4 <= 16 AND nP2 <= 9:
Repeat **Until** *2L (2R, m/4C) H1* and *1L (3R, n/3C) H2* are filled:
Load mP4 in H1
Load nP2 in H2
ELSE IF mP4 <= 24 AND nP2 <= 9:
Repeat **Until** *2L (2R, m/4C) H1*, *1L (3R, n/3C) H2*, and *2L (2R, m/4C)* H2 are filled:
Load mP4 in H1
Load nP2 in H2
Load nP4 in H2
ELSE IF mP4 <= 32 AND nP2 <= 21:
Repeat **Until** *2L (2R, m/4C) H1*, *1L (3R, n/3C) H2*, and *2L (2R, m/4C)* H2 are filled:
Load mP4 in H1
Load nP2 in H2
Load mP4 in H2
ELSE IF mP4 < nP2 AND mP4 <= 9:
Repeat **Until** *1L (3R, n/3C)* is filled:
Load nP2
Put the remaining mP4 in the buffer
END WHILE

Algorithm for Expedition

- In order to speed up and automate the loading procedure, I created the fictitious algorithm for expedition.
- It guarantees reliable and effective loading operations by using an organized and explicit methodology.
- The technique makes it simple to replicate and apply to various missions, which reduces errors and saves time.
- By maximizing the use of available space inside the vehicle, it increases the number of pallets that can be transported.
- The program also takes into account various circumstances and priorities to make sure that particular pallet combinations are loaded strategically.
- Only 5 products come and stays out of expedition.

IF *P4(3)* AND *P2(2)* are available:
Load *P4 (2R, 1C)* in Layer 2
Load *P2 (2R, 1C)* in Layer 1
Put *P4(1)* in the buffer
ELSE IF P2(3) AND P4(2) are available:
Load *P2 (3R, 1C)* in Layer 1
Load *P4 (2R, 1C)* in Layer 2
ELSE IF P4(4) AND P2(1) are available:
Load P4 in *2L (2R, 1C)*
Put P2(1) in the buffer
ELSE IF P2(4) AND P4(1) are available:
Load *P2* in *1L (3R, 1U)*
Load *P4 (1R, 1C)* above P2
Put P2(1) in the buffer
ELSE IF 5P4 OR 5P2 is available:
Load *2L (2R, 1C)* of P4 or P2
Put the remaining P4 or P2 in the buffer
IF all conditions are true:
Load until the truck is full
ELSE:
Load available pallets by priority
END IF

Overall, the pseudo algorithm improves the expedition process by offering a methodical loading technique that results in cost-effectiveness.

6.5 Capacity equation

A capacity equation in logistics is a mathematical formula used to calculate a process's maximum transportation capacity. The maximum number of units that can be transported in a specific amount of time, taking into consideration factors like available resources, labour, and equipment, is often calculated in logistics.

- The capacity equation is done for both the truck space and labour.
- LD+ULD – Loading and unloading timing.
- T – Transport timing
- D- Drazice, L – Lustenice, W – Warehouse

Table 8 Loading unloading and transport time for capacity equations [Source: Own]

	Location									
	Current				Optimised					
Time	D-W (min)OL1		L_W (min)OL2		D-W (min)NL3		L_W (min)NL2		D_W (min)NL1	
	T	LD+ULD	T	LD+ULD	T	LD+ULD	T	LD+ULD	T	LD+ULD
TransportTime	8	38	2	32	8	45	2	47	8	44

- The Number of batches mentioned has the data of number of pallets transported in each loading.
- With that information we know how many times a labour has to move pallets inside the trucks and how long it takes.

Table 9 Labour movement [Source: Own]

Required number of transport into trucks	Labour movement (no of times)				
	OL1	OL2	NL3	NL2	NL1
	16	21	16	17	17

- Number of labours required in each activity is 1.
- For calculation of utilisation, we need to know the available time that is given in table 11.

Table 10 Available time [Source: Own]

	Available time				
	OL1	OL2	NL3	NL2	NL1
DAYS	1	1	1	1	1
SHIFT (HRS)	8	8	8	8	8
SHIFT MIN	480	480	480	480	480
BRAKES (min)	50	50	50	50	50
TIME PER SHIFT (min)	430	430	430	430	430
NO OF SHIFT	2	2	2	2	2
TOTAL TIME (min)	860	860	860	860	860

- Utilization in capacity planning refers to the extent to which a system or resource is being used to fulfil demand. The amount of the available capacity that is being used is frequently stated as a percentage.
- Utilization of labour in specific time is the percentage of time demand of two trucks by total time.

Table 11 Truck and labour utilization [Source: Own]

	Truck and labour UTILAIZATION (%)				
	OL1	OL2	NL3	NL2	NL1
TIME DEMAND for 2 trucks (min)	1408	1450	1568	1656	1658
TIME AVAILABILITY (min)	960	960	960	960	960
THEORY NO OF TRUCKS	1.47	1.51	1.63	1.73	1.73
NO OF TRUCKS	2	2	2	2	2
TOTAL TIME AVAILABLE (min)	1920	1920	1920	1920	1920
UTILILAIZATION (%)	73.33%	75.52%	81.67%	86.25%	86.35%

Thus, we can see the utilization percentage of each loading method in table 12. It has improved with the new loading methods.

- Utilization of space is another major concept that we should consider.
- The available truck space along with the pallet size is given in table 13.

Table 12 Available truck space [Source: Own]

Available truck space				
	Length (m)	Breath (m)	Height (m)	Capacity (m)
Truck	9.67	2.45	2.82	66.81
P2	1.35	0.75	1.4	1.42
P4	1.2	1.2	1.2	1.73

- Utilization = Required space/Total space
- The utilization of space of each loading type is give in table 14.

Table 13 Utilization of space [Source: Own]

	UTILAIZATION OF SPACE (%)				
	OL1	OL2	NL3	NL2	NL1
Number of pallets	16	21	32	33	25
Available truck space	66.81	66.81	66.81	66.81	66.81
Recquired truck space	27.65	29.77	55.30	55.96	40.41
Number of trucks	1.00	1.00	1.00	1.00	1.00
TOTAL space AVAILABLE (min)	66.81	66.81	66.81	66.81	66.81
UTILILAIZATION (%)	41.38%	44.56%	82.77%	83.76%	60.48%

- Thus, from the table 14 it is evident that the loading arrangements are efficient enough as the utilisation is comparatively more.
- These data had a major point on deciding the timings of the activities for the new schedule.

6.6 Simulation of New schedule

The process of simulating a real-world system or event in order to research, analyse, or forecast how the system will behave in various situations is known as simulation. To replicate the system's behaviour over time, a mathematical or computational model of the system must be created.

- In its broadest meaning, simulation does not always require specialized software tools. It can also be used to describe the process of creating and assessing alternative schedules or situations in order to determine their effects and make wise judgments.
- Simulating the process of creating a new schedule can include data analysis and manipulation, taking into account various limitations and circumstances, and repeatedly altering variables to obtain the best outcome.
- By simulating and investigating possible implications of schedule modifications without actually executing them, this technique helps firms reduce risks and expenses.

- Businesses can make data-driven decisions and create efficient schedules that optimize resources, reduce disruptions, and boost operational efficiency by using simulation approaches.
- This schedule is drawn for two trucks and four drivers who works in two shifts.
- List of activities are also reduced compared to the current state.

A newly created transportation schedule that calls for fewer transportation and comparatively fewer delay for truck 1 is given in the figure 29. The schedule of the truck 2 is given in the attachment 8.

Activity	Shift	Task allocated	Daily activity	Start	End	Task timing (min)
1	1	Driver 1	Loading @ D	06:00	06:30	30.00
2	1	Driver 1	Transport to W	06:30	06:38	8.00
3	1	Driver 1	Unloading @ w	06:38	06:58	20.00
4	1	Driver 1	Transport to L	06:58	07:00	2.00
5	1	Driver 1	Loading @ L	07:00	07:30	30.00
6	1	Driver 1	Transport to W	07:30	07:32	2.00
7	1	Driver 1	Unloading @ W	07:32	07:52	20.00
8	1	Driver 1	Transport to D	07:52	08:00	8.00
9	1	Driver 1	Break 1	08:00	08:05	5.00
10	1	Driver 1	Loading @ D	08:05	08:35	30.00
11	1	Driver 1	Transport to W	08:35	08:43	8.00
12	1	Driver 1	Unloading @ W	08:43	09:03	20.00
13	1	Driver 1	Loading pallets	09:03	09:18	15.00
14	1	Driver 1	Transport to D	09:18	09:26	8.00
15	1	Driver 1	Unloading pallets	09:26	09:40	14.00
16	1	Driver 1	Loading @ D	09:40	10:07	27.00
17	1	Driver 1	Transport to W	10:07	10:15	8.00
18	1	Driver 1	Lunch Break	10:15	10:45	30.00
19	1	Driver 1	Unloading @ w	10:45	11:05	20.00
20	1	Driver 1	Transport to L	11:05	11:07	2.00
21	1	Driver 1	Loading @L	11:07	11:37	30.00
22	1	Driver 1	Transport to W	11:37	11:40	3.00
23	1	Driver 1	Fuel refill	11:40	11:50	10.00
24	1	Driver 1	Unloading @ W	11:50	12:10	20.00
25	1	Driver 1	Break 3	12:10	12:15	5.00
26	1	Driver 1	Transport to L	12:15	12:17	2.00
27	1	Driver 1	Loading @ L	12:17	12:47	30.00
28	1	Driver 1	Transport to W	12:47	12:50	3.00
29	1	Driver 1	Unloadiong @ W	12:50	13:05	15.00
30	1	Driver 1	Transport to D	13:05	13:13	8.00
31	1	Driver 1	Loading @ D	13:13	13:43	30.00
32	1	Driver 1	Transport to W	13:43	13:50	7.00
33	1	Driver 1	Break 4	13:50	14:00	10.00
Shift ends						
34	2	Driver 3	Unloading @ w	14:00	14:20	20.00
35	2	Driver 3	Transport to L	15:00	14:22	2.00
36	2	Driver 3	Loading @ L	16:00	14:52	30.00
37	2	Driver 3	Transport to W	17:00	14:54	2.00
38	2	Driver 3	Unloading @ W	18:00	15:14	20.00
39	2	Driver 3	Transport to D	19:00	15:44	30.00
40	2	Driver 3	Loading @ D	20:00	16:00	16.00
41	2	Driver 3	Break 1	21:00	16:05	5.00
42	2	Driver 3	Loading @ D	22:00	16:20	15.00
43	2	Driver 3	Transport to W	23:00	16:28	8.00
44	2	Driver 3	Unloading @ W	00:00	16:48	20.00
45	2	Driver 3	Loading pallets	01:00	17:03	15.00
46	2	Driver 3	Transport to D	02:00	17:11	8.00
47	2	Driver 3	Unloading pallets	03:00	17:25	14.00
48	2	Driver 3	Loading @ D	04:00	17:52	27.00
49	2	Driver 3	Transport to W	05:00	18:00	8.00
50	2	Driver 3	Unloading @ W	06:00	18:15	15.00
51	2	Driver 3	Lunch Break	07:00	18:45	30.00
52	2	Driver 3	Transport to L	08:00	18:47	2.00
53	2	Driver 3	Loading @L	09:00	19:17	30.00
54	2	Driver 3	Transport to W	10:00	19:20	3.00
55	2	Driver 3	Fuel refill	11:00	19:30	10.00
56	2	Driver 3	Unloading @ W	12:00	19:50	20.00
57	2	Driver 3	Transport to L	13:00	19:52	2.00
58	2	Driver 3	Loading @ L	14:00	20:10	18.00
59	2	Driver 3	Break 3	15:00	20:15	5.00
60	2	Driver 3	Loading @ L	16:00	20:27	12.00
61	2	Driver 3	Transport to W	17:00	20:30	3.00
62	2	Driver 3	Unloadiong @ W	18:00	20:45	15.00
63	2	Driver 3	Transport top L	19:00	20:47	2.00
64	2	Driver 3	Loading @ L	20:00	21:17	30.00
65	2	Driver 3	Transport to W	21:00	21:20	3.00
66	2	Driver 3	Unloading @ W	22:00	21:40	20.00
67	2	Driver 3	Transport to D	23:00	21:50	10.00
68	2	Driver 3	Break 4	21:50	22:00	10.00
Shift ends						

Figure 29 New schedule for Truck 1

7 Compare the designed logistic model with the current state of the system

The suggested logistic model offers notable advancements over the present situation.

- First of all, it brings a methodical, planned approach to logistics operations, doing away with ad hoc decision-making and boosting general effectiveness.
- The model uses optimization approaches to improve load distribution, resource allocation, and route planning, which lowers transportation costs and accelerates delivery times.

7.1 Algorithmic Loading tool

- An algorithmic loading tool using Excel have been developed that allows users to visualize the loading arrangement based on given values of P4 and P2.
- This tool is designed with reference to the loading algorithm, ensuring accuracy and adherence to the defined loading rules.
- With this tool, users can input the quantities of P4 and P2, and the tool automatically generates a loading plan, showcasing the arrangement of pallets in different layers and columns.
- The tool provides a clear and intuitive representation of the loading configuration, enabling users to optimize space utilization and ensure efficient loading.
- Additionally, the tool offers flexibility, allowing users to quickly adjust the input values and generate updated loading plans.
- Overall, this algorithmic loading tool simplifies the loading process and aids in effective logistics planning and decision-making.

P2	P4
9	16

- This is the place where the Values of P4 and P2 is given so that the output will be displaying the loading arrangement in a graphical way.
- The display for the arrangement for the above given value is given in figure 31.

Loading Types	P2	P4
OL1		16
OL2	21	
NL1	9	16
NL2	9	24
NL3		32

P2	P4
9	16

		9		
P2	1	1	1	1
	1	1	1	2
	1	1	1	3
	0	0	0	4
	0	0	0	5
	0	0	0	6
	0	0	0	7

		16	
P4	2	2	1
	2	2	2
	2	2	3
	2	2	4
	0	0	5
	0	0	6
	0	0	7
	0	0	8

Buffer	0

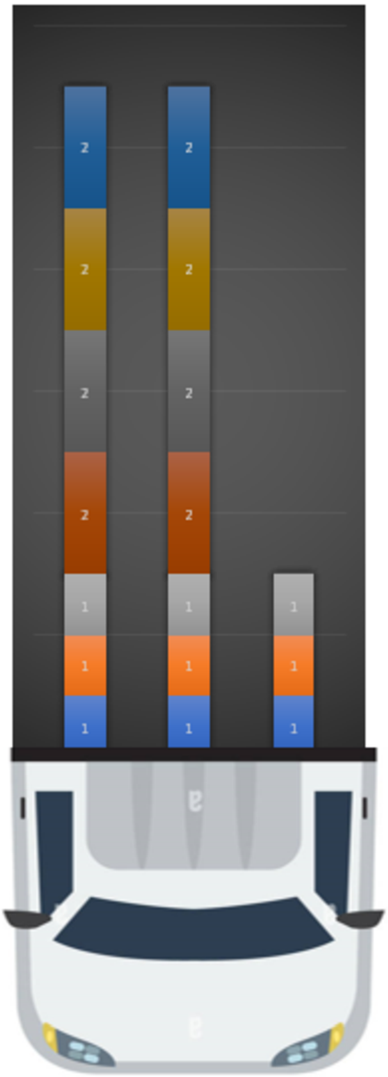


Figure 30 Algorithmic loading [Source: Own]

Figure 31 shows the loading arrangement for the given value, where the number 2 indicates the number of pallet layers (2 = 2 layers, 1 = 1 layer). The graph displays P2 pallets in three rows and P4 pallets in two rows, reflecting the different dimensions of the pallets. This arrangement ensures optimal utilization of space and efficient stacking of the pallets.

This tool has certain constraints that impact its functionality and visual representation. One limitation is that it can only display the predefined loading arrangements, such as OL1, OL2, and so on, making it challenging to accommodate custom or alternative loading configurations. Additionally, while the tool provides information on the remaining items in the buffer, it lacks visibility on the actual availability of P4 and P2 pallets, which limits its ability to accurately assess and optimize the loading process.

Moreover, the tool imposes a maximum limit of 33 for graphical visualization, which means that any scenario involving a higher number of pallets cannot be effectively represented. This limitation can hinder the tool's usefulness when dealing with larger-scale operations or complex loading arrangements.

Furthermore, even within the defined constraints, there are certain combinations of pallets that the tool cannot display, regardless of the total number of pallets being below the limit. This can restrict the user's ability to explore and visualize all possible loading configurations, potentially limiting their decision-making process and optimization efforts.

Algorithmic loading Tool Testing and results

A thorough testing process was used to assure the accuracy and dependability of the algorithmic loading tool.

- To verify the tool's capacity to produce accurate loading arrangements, test scenarios with various P4 and P2 concentrations were developed.
- To ensure that the tool accurately reproduced the anticipated outcomes, established loading combinations were used as test subjects.
- The P2 pallets are displayed in 3 rows and P4 pallets are displayed in 2 rows. The number written on each box states the number of pallets (**2** = Two pallets one above the other).
- The tested values and its results are given in figure 31.

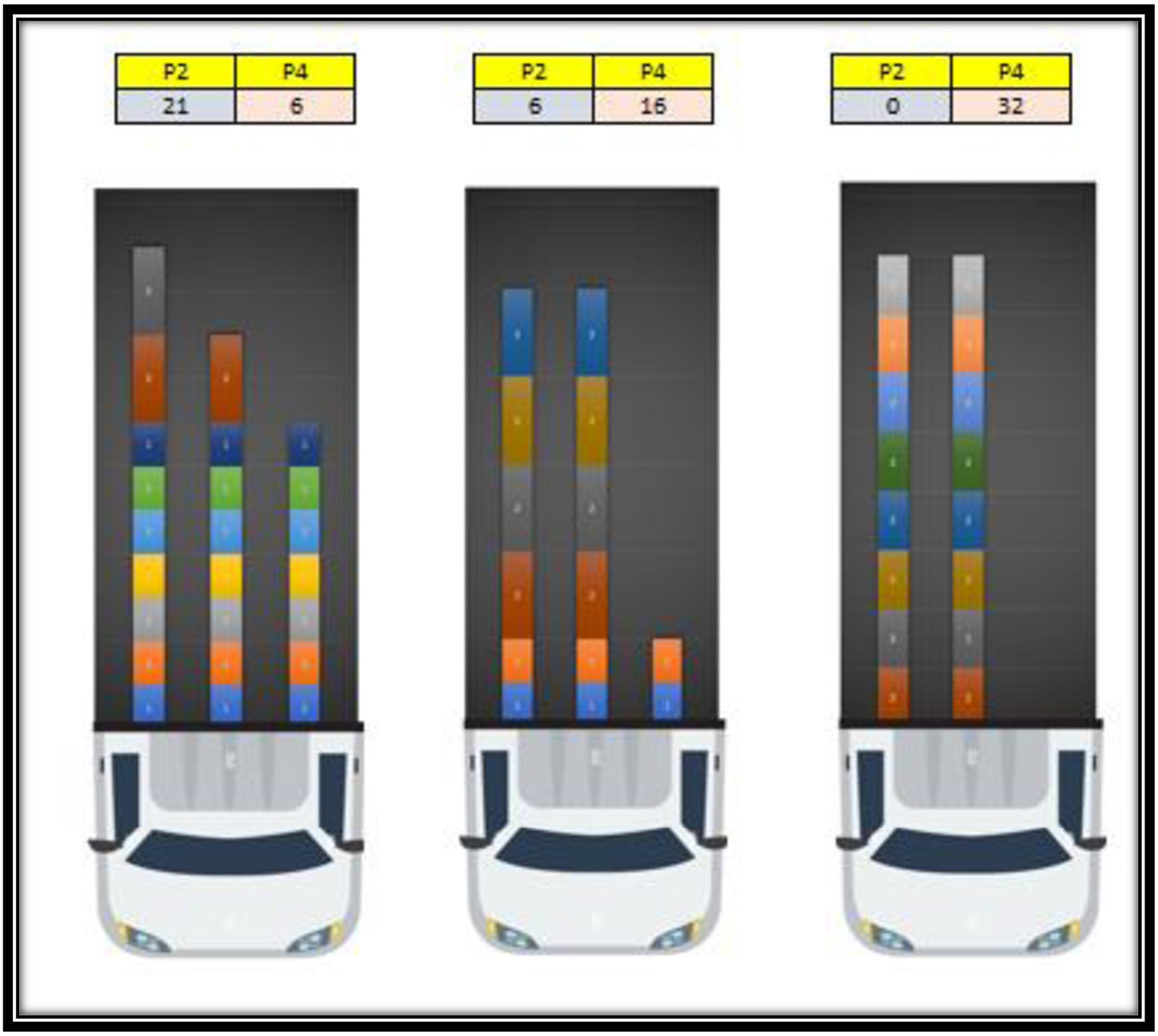


Figure 31 Algorithmic loading test results [Source: Own]

- This tool can make the loading visualisation in 2d easier. Before every transport, by knowing the available number of pallets we can visualize how the loading arrangement should look like.

7.2 New schedule testing and results

Interpretation

- The newly developed schedule provides a practical method to evaluate and improve logistics.
- The schedule algorithm determines the necessary number of transports by taking into consideration loading time and batch size and the number of products for a given day's production.
- Based on the estimated transportation requirements, a timetable that only contains the essential operations is subsequently generated dynamically.
- By streamlining the process, it is possible to allocate resources more effectively and do away with pointless tasks, which increases productivity and frees up time.
- The output of the schedule is displayed as a Gantt chart, which gives a visual depiction of the scheduled tasks, their durations, and their interdependencies.
- If the transportation requirements can be completed within a specific timeframe, any remaining time will be displayed as free time in the schedule.
- The loading process is allocated 30 minutes in the schedule. Taking into account productivity and the availability of finished pallets, the loading arrangement needs to be determined.
- It is crucial to complete the loading before the truck's waiting time of 30 minutes in the loading area.
- Efficient selection and organization of the loading process are essential to ensure timely completion within the allocated time frame.
- This ensures optimal utilization of resources and avoids unnecessary delays, maximizing efficiency in the logistics operation.
- The schedule is carefully designed to ensure that both the truck's starting and ending points are at Drazice. This allows for efficient logistics operations and simplifies planning. Breaks are scheduled according to the production needs, eliminating the need for additional adjustments.
- By strategically incorporating breaks into the schedule, it ensures that the truck operates smoothly throughout the day, maintaining a consistent workflow.
- The truck can complete its tasks within the allocated time without the need for unnecessary modifications, optimizing time management and overall productivity

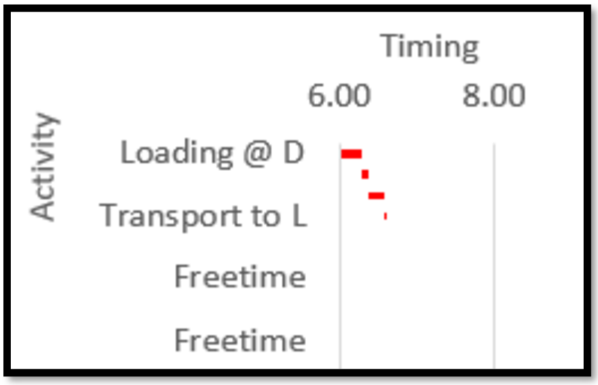
Test result 1

No of Product	50		Freetime

Activity	Shift	Task allocated	Daily activity	Start	End	Task timing (hr)
1	1	Driver 1	Loading @ D	6.00	6.30	0.30
2	1	Driver 1	Transport to W	6.30	6.38	0.08
3	1	Driver 1	Unloading @ w	6.38	6.58	0.20
4	1	Driver 1	Transport to L	6.58	7.00	0.02
5	1	Driver 1	Freetime	Freetime	Freetime	Freetime
6	1	Driver 1	Freetime	Freetime	Freetime	Freetime

Figure 32 New loading test result 1 [Source: Own]

- The schedule for one truck includes the testing of 50 products is given in figure 32, displaying the duration required for their transportation. Any remaining time slots in the schedule are marked as free time.
- This allows for better resource management and enables planners to identify available slots for potential additional tasks or adjustments. By clearly depicting the timing of transportation and showcasing the gaps as free time, the schedule provides a comprehensive overview of the truck's activities throughout the day.



Graph 7 New schedule Test result 1 [Source: Own]

- The Gantt chart provides a visual representation of the schedule, highlighting the allocated time for each activity and indicating the periods of free time which is given in the graph 7.

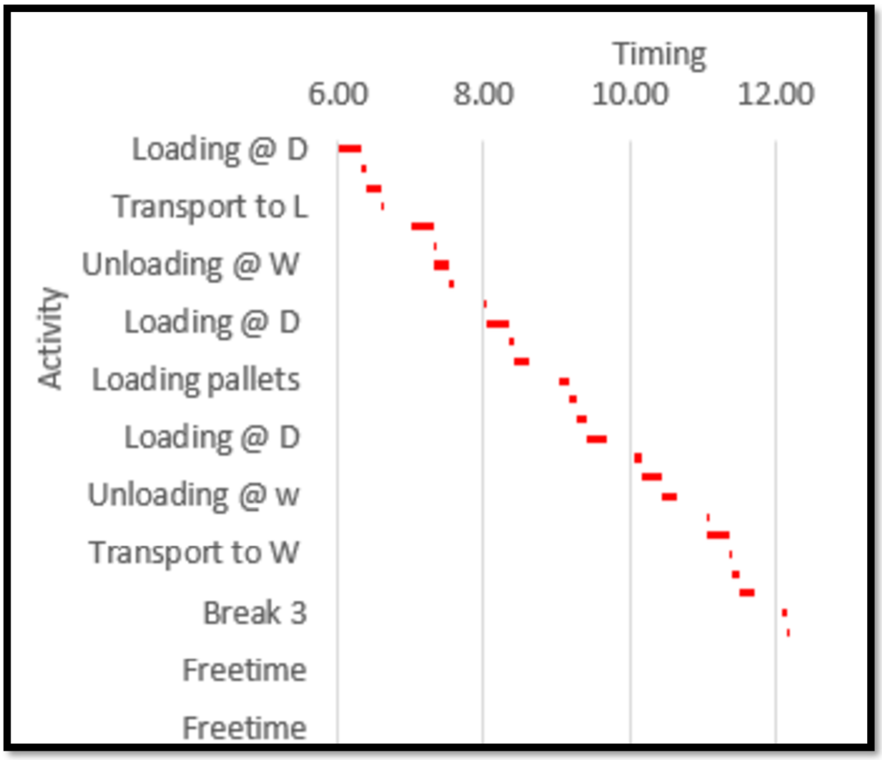
Test result 2

No of Product	190		Freetime

Activity	Shift	Task allocated	Daily activity	Start	End	Task timing (hr)
1	1	Driver 1	Loading @ D	6.00	6.30	0.30
2	1	Driver 1	Transport to W	6.30	6.38	0.08
3	1	Driver 1	Unloading @ w	6.38	6.58	0.20
4	1	Driver 1	Transport to L	6.58	7.00	0.02
5	1	Driver 1	Loading @ L	7.00	7.30	0.30
6	1	Driver 1	Transport to W	7.30	7.32	0.02
7	1	Driver 1	Unloading @ W	7.32	7.52	0.20
8	1	Driver 1	Transport to D	7.52	8.00	0.08
9	1	Driver 1	Break 1	8.00	8.05	0.05
10	1	Driver 1	Loading @ D	8.05	8.35	0.30
11	1	Driver 1	Transport to W	8.35	8.43	0.08
12	1	Driver 1	Unloading @ W	8.43	9.03	0.20
13	1	Driver 1	Loading pallets	9.03	9.18	0.15
14	1	Driver 1	Transport to D	9.18	9.26	0.08
15	1	Driver 1	Unloading pallets	9.26	9.40	0.14
16	1	Driver 1	Loading @ D	9.40	10.07	0.27
17	1	Driver 1	Transport to W	10.07	10.15	0.08
18	1	Driver 1	Lunch Break	10.15	10.45	0.30
19	1	Driver 1	Unloading @ w	10.45	11.05	0.20
20	1	Driver 1	Transport to L	11.05	11.07	0.02
21	1	Driver 1	Loading @L	11.07	11.37	0.30
22	1	Driver 1	Transport to W	11.37	11.40	0.03
23	1	Driver 1	Fuel refill	11.40	11.50	0.10
24	1	Driver 1	Unloading @ W	11.50	12.10	0.20
25	1	Driver 1	Break 3	12.10	12.15	0.05
26	1	Driver 1	Transport to L	12.15	12.17	0.02
27	1	Driver 1	Freetime	Freetime	Freetime	Freetime
28	1	Driver 1	Freetime	Freetime	Freetime	Freetime
29	1	Driver 1	Freetime	Freetime	Freetime	Freetime
30	1	Driver 1	Freetime	Freetime	Freetime	Freetime
31	1	Driver 1	Freetime	Freetime	Freetime	Freetime

Figure 33 New loading test result 2 [Source: Own]

- In this test, the schedule for one truck includes the transportation of 190 products is given in Figure 33, indicating the corresponding duration for each task.
- Any unallocated time slots in the schedule are displayed as free time, providing flexibility for potential adjustments or additional tasks.
- The Gantt chart visually represents the timeline, showcasing the allocated periods for transportation and highlighting the periods of available free time is given in graph 8.



Graph 8 New schedule test result 2 [Source: Own]

Test result 3

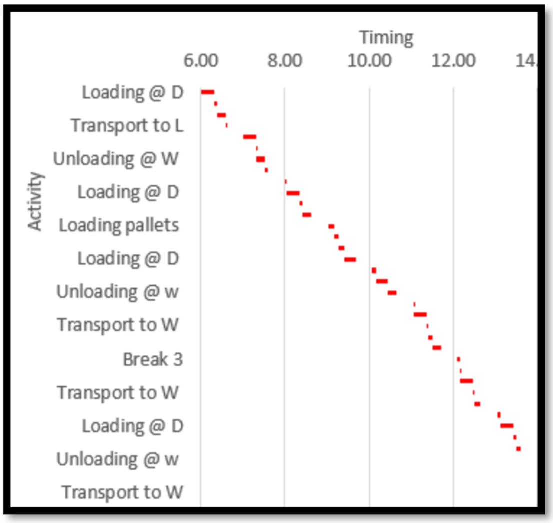
- The schedule accommodates the transportation of 320 products, slightly exceeding the production limit of 300 is given in Figure 34.
- It showcases the precise duration required for each task, covering the entire schedule. Notably, this comprehensive schedule demonstrates its applicability across different production levels, ranging from low to medium and high.
- With its versatility and adaptability, the schedule proves effective in managing various production volumes, optimizing resource utilization, and ensuring efficient transportation operations
- Through careful testing and verification, it has been established that the schedule effectively caters to low, medium, and high production requirements. It ensures that all production quantities can be transported within the designated time frame, promoting seamless operations and minimizing delays. The complete schedule and its gantt charts of two trucks are given in attachments 9,10,1 and 12.

No of Product	320		Freetime		

Activity	Shift	Task allocated	Daily activity	Start	End	Task timing (hr)
1	1	Driver 1	Loading @ D	6.00	6.30	0.30
2	1	Driver 1	Transport to W	6.30	6.38	0.08
3	1	Driver 1	Unloading @ w	6.38	6.58	0.20
4	1	Driver 1	Transport to L	6.58	7.00	0.02
5	1	Driver 1	Loading @ L	7.00	7.30	0.30
6	1	Driver 1	Transport to W	7.30	7.32	0.02
7	1	Driver 1	Unloading @ W	7.32	7.52	0.20
8	1	Driver 1	Transport to D	7.52	8.00	0.08
9	1	Driver 1	Break 1	8.00	8.05	0.05
10	1	Driver 1	Loading @ D	8.05	8.35	0.30
11	1	Driver 1	Transport to W	8.35	8.43	0.08
12	1	Driver 1	Unloading @ W	8.43	9.03	0.20
13	1	Driver 1	Loading pallets	9.03	9.18	0.15
14	1	Driver 1	Transport to D	9.18	9.26	0.08
15	1	Driver 1	Unloading pallets	9.26	9.40	0.14
16	1	Driver 1	Loading @ D	9.40	10.07	0.27
17	1	Driver 1	Transport to W	10.07	10.15	0.08
18	1	Driver 1	Lunch Break	10.15	10.45	0.30
19	1	Driver 1	Unloading @ w	10.45	11.05	0.20
20	1	Driver 1	Transport to L	11.05	11.07	0.02
21	1	Driver 1	Loading @L	11.07	11.37	0.30
22	1	Driver 1	Transport to W	11.37	11.40	0.03
23	1	Driver 1	Fuel refill	11.40	11.50	0.10
24	1	Driver 1	Unloading @ W	11.50	12.10	0.20
25	1	Driver 1	Break 3	12.10	12.15	0.05
26	1	Driver 1	Transport to L	12.15	12.17	0.02
27	1	Driver 1	Loading @ L	12.17	12.47	0.30
28	1	Driver 1	Transport to W	12.47	12.50	0.03
29	1	Driver 1	Unloadiong @ W	12.50	13.05	0.15
30	1	Driver 1	Transport to D	13.05	13.13	0.08
31	1	Driver 1	Loading @ D	13.13	13.43	0.30
32	1	Driver 1	Transport to W	13.43	13.50	0.07
33	1	Driver 1	Break 4	13.50	14.00	0.10
Shift ends						

Figure 34 New loading test result 3 [Source: Own]

- By successfully managing the logistics for high production, the schedule demonstrates its reliability and scalability. It emphasizes the importance of strategic planning and resource allocation to ensure timely delivery of products.



Graph 9 New schedule test result 3 [Source: Own]

- The presented graph 9 provides a comprehensive overview of the complete schedule for the entire day, showcasing the transportation requirements for different production levels. It becomes evident that high production necessitates a substantial number of transports, indicating the increased demand for efficient logistics management. The schedule takes into account the loading arrangement, which proves to be a crucial factor in accommodating varying production volumes.

7.3 Comparison

- When comparing the new logistic model with the current state, it becomes apparent that the new system addresses the drawbacks present in the previous approach. The implementation of new loading arrangements and an optimized schedule has significantly enhanced the efficiency of transporting even high production volumes.
- One of the key improvements lies in the framing and optimization of the schedule. By carefully allocating time slots and resources, the new logistic model ensures that the transportation process operates smoothly and effectively. The schedule takes into account various factors such as loading time, activity duration, and productivity levels, resulting in a well-structured and coordinated workflow.
- Furthermore, the performance of the schedule has been thoroughly tested, confirming its reliability and effectiveness across different working conditions. Whether it is low, medium, or high production, the schedule demonstrates its capability to handle the

workload efficiently. It provides a robust framework for meeting customer demands within the designated time frame.

- One notable achievement is the reduction in the number of activities while increasing the duration of each activity. This indicates better utilization of resources and improved productivity. The optimized schedule ensures that tasks are completed with minimal interruptions and delays, allowing for a streamlined and seamless transportation process.
- Overall, the new logistic model surpasses the limitations of the current state by introducing innovative loading arrangements, an optimized schedule, and thorough performance testing. It enables efficient transportation even for high production volumes, ensuring timely delivery and customer satisfaction. The reduction in activity count and increased duration reflects improved resource utilization and enhanced productivity. The new logistic system proves to be a valuable asset in optimizing operations and maximizing efficiency in the logistics process.

7.4 Transportation fuel cost comparison

Table 14 Truck fuelling cost [Source: Own]

Truck mileage (km/lit)	3.8
Fuel cost per lit (czk)	27
Fuel consumption (lit/km)	0.26
Cost per km (czk)	7

Drazice trucks are fuelled inside Drazice itself as they have own gas station. The fuel cost is comparatively less. Truck milage and fuel costs are given in table 15. We are going to compare the transportation cost of old and new logistic system with the required number of transports alone.

Drazice (OL1 Vs NL3)

The cost comparison between the old and new logistic models reveals a significant reduction in transport expenses from Drazice to the warehouse, that is given in table 16. The old model incurred a cost of 2,71,040czk, while the new model significantly lowers the cost to 1,35,520czk. This represents a 50% reduction in transport expenses, highlighting the substantial difference achieved through the implementation of the new logistic system.

Table 15 Comparison Drazice [Source: Own]

Comparison @ Drazice	Old	New
Distance (Km)	8	8
Number of recquired transports	10	5
Transport time (Mins)	10	8
Total distance (Km)	160	80
Transportation fuel cost per week (Czk)	1.120	560
Transportation fuel cost per month (czk)	2.464	12.320
Transportation Fuel cost per year (czk)	271.040	135.520

The cost comparison between the old and new logistic models reveals a significant reduction in transport expenses from Drazice to the warehouse. The old model incurred a cost of 271.040,00czk, while the new model significantly lowers the cost to 135.520,00czk. This represents a 50% reduction in transport expenses, highlighting the substantial difference achieved through the implementation of the new logistic system.

Lustenice OL2 vs NL1

Table 16 Comparison Lustenice [Source: Own]

Comparison @ Lustince	Old	New
Distance (Km)	0.5	0.5
Number of recquired transports	14	8
Transport time (Mins)	2	2
Total distance (Km)	14	8
Transportation fuel cost per week (Czk)	98	56
Transportation fuel cost per month (czk)	2.156	1.232
Transportation Fuel cost per year (czk)	23.716	13.552

When considering the fuel cost comparison of transport between lustenice to warehouse that is given in table 17. The old model incurred a cost of 23.716,00czk, while the new model significantly lowers the cost to 13.552,00czk.

When considering the cost reduction on an annual basis, the impact becomes even more pronounced. With the old model, the annual transport cost would amount to a considerable sum.

However, the new logistic model slashes this cost to a significantly lower level, indicating a remarkable improvement in cost efficiency.

7.5 Suggestion about alternative mode of transport

- When considering AGVs for pallet transport, some notable models can carry either one or two pallets at a time like ethe models given in the figure 35. While there are AGVs capable of carrying more, their exact costs are unknown. Therefore, other factors become important, such as the number of products that can be transported within a given time period, energy consumption, and additional supporting elements required for the task. Furthermore, due to the limitations of individual AGVs, multiple units may be necessary, along with the need for automatic loading and unloading systems or additional labour, which adds to the overall transport cost.

Figure 35 Pallet carrying AGVs [26]

- In analysing the alternatives of rail transport and Automated Guided Vehicles (AGV) in comparison to truck usage, several factors need to be considered. Firstly, it is important to note that the current trucks already fulfil the required activities, and the implementation of the new logistic model has effectively reduced transportation costs. Therefore, there may be no immediate need to switch to AGV or rail transport.

- AGV or robotic vehicles are better suited for operations on flat surfaces, but the area from Lustenice to the warehouse comprises rough roads. This rugged terrain can complicate the movements of AGVs and limit their effectiveness. Additionally, weather conditions such as heavy snowfall or intense sunlight can further hinder transportation in open spaces, potentially causing delays or disruptions.
- Another aspect to consider is the setup cost associated with implementing AGV or robotic vehicles. The initial investment required for acquiring and integrating this technology can be substantial. Additionally, the maintenance cost of AGVs and robotic vehicles needs to be considered, as any malfunctions or breakdowns can result in downtime and additional expenses.
- Similarly, rail transport also presents challenges. The setup cost for establishing rail infrastructure, including tracks and stations, is significantly high. Moreover, rail transport may not be suitable for all climatic conditions, and extreme weather events can impact its operation. Additionally, the reliance on rail transport may require increased labour resources for loading and unloading goods, adding to operational complexities.

Taking all these factors into account, it appears that maintaining the transportation process with trucks is the most feasible option. The current trucks are already equipped to handle the required activities, and the implemented logistic model has effectively reduced transportation costs. Considering the rugged terrain, unpredictable weather conditions, high setup costs, maintenance expenses, and labour requirements associated with AGV and rail transport, it seems more practical to continue utilizing trucks for the transportation needs.

8 Conclusion

In conclusion, my logistic problem regarding the adequacy of trucks for transportation has been effectively addressed through a comprehensive analysis and optimization process. Initially, there was confusion and complaints from workers about the insufficiency of trucks. To overcome this, ABC analysis is conducted to identify the most valuable products, allowing me to prioritize and focus on their logistic processes.

To gain a deep understanding of the entire industry's material and information flow, utilized process diagrams and descriptions were used. Task timings and activity durations were meticulously calculated through chronometry, enabling me to accurately assess the logistics operations. Transport routes and distances were carefully mapped out, facilitating efficient planning.

One significant aspect of the work was the development of a new loading algorithm that considered loading arrangements and ensured the creation of the required number of transports. Incorporating this algorithm into a loading tool, allowing for quick and accurate display of loading setups based on given pallet quantities and it has some constrains. The utilization of the new logistic model was assessed using capacity equations, demonstrating improved utilization results compared to the previous system.

Drawing on these findings, a new schedule was created that significantly reduced delays and improved overall performance. Rigorous testing validated the effectiveness of the schedule across different production types, even during periods of excess production.

Consequently, it became evident that the existing two trucks were more than sufficient to meet the transportation needs with the newly designed logistic system loading, eliminating the need to purchase additional vehicles or explore alternative transport options.

Furthermore, this thesis affirmed that the current fleet of material handling equipment was capable of seamlessly executing the work in accordance with the new schedule. The results obtained from the analysis, optimization, and testing processes support the conclusion that the logistic operations have been streamlined and optimized, resulting in improved efficiency and cost-effectiveness.

In conclusion, the implementation of the new schedule and logistic model, supported by thorough analysis and testing, has successfully resolved the initial concerns regarding truck adequacy. The optimized processes, reduced delays, and enhanced utilization demonstrate the effectiveness of the proposed approach. This research provides valuable insights and a practical framework for efficient logistic management, offering a foundation for continued improvement in the future.

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Attachments

Attachment number 1: ABC analysis

	2022	Total	Percentage		ABC
1	NAD 100 v1, NAD 50 v1	21755	8.94	8.94	A
2	OKCE 125	15359	6.31	15.26	
3	OKCE 80	12425	5.11	20.36	
4	OKC 300 NTR/HP	9882	4.06	24.43	
5	OKCE 160	9667	3.97	28.40	
6	OKC 125	7032	2.89	31.29	
7	OKC 125 NTR/HV	6799	2.79	34.09	
8	OKC 200 NTR/HP	6611	2.72	36.80	
9	OKC 250 NTR/HP	6598	2.71	39.52	
10	OKCE 100	6562	2.70	42.21	
11	OKC 160	6224	2.56	44.77	
12	TO-20	5939	2.44	47.21	
13	OKCE 200	5648	2.32	49.54	
14	NAD 250	5346	2.20	51.73	
15	OKC 300 NTRR/SOL	4722	1.94	53.68	
16	OKCE 50	4477	1.84	55.52	
17	250 LTS - TOP	4096	1.68	57.20	
18	OKC 200	3919	1.61	58.81	
19	OKC 100 NTR	3575	1.47	60.28	
20	OKCV 160	3420	1.41	61.69	
21	OKCV 125	3051	1.25	62.94	
22	OKC 160 NTR/HV	2868	1.18	64.12	
23	OKC 160/1m2	2665	1.10	65.21	
24	OKC 200 NTR/BP	2455	1.01	66.22	
25	NAD 1000 l	2444	1.00	67.23	
26	OKC 125/1m2	2364	0.97	68.20	
27	NAD 750 l	2345	0.96	69.16	
28	OKCEV 125	2338	0.96	70.13	
29	OKCEV 160	2273	0.93	71.06	
30	OKCV 200	2273	0.93	71.99	
31	OKC 100 NTR/HV	2064	0.85	72.84	
32	OKC 200/1m2	2061	0.85	73.69	
33	NADO 500 l	2037	0.84	74.53	
34	OKC 80	2033	0.84	75.36	
35	OKC 100	1918	0.79	76.15	
36	OKH 125 NTR/HV	1861	0.77	76.92	
37	OKCE 200 S/2,2kW	1812	0.74	77.66	
38	OKC 200 NTRR/SOL	1808	0.74	78.41	
39	OKC 160 NTR/BP	1802	0.74	79.15	
40	OKC 200 NTRR/SOL	1800	0.74	79.89	
41	OKCE 125 S/2,2kW	1762	0.72	80.61	B
42	OKHE 160	1757	0.72	81.33	

43	OKC 160 NTR	1717	0.71	82.04	
44	OKHE 125	1712	0.70	82.74	
45	OKCEV 100	1591	0.65	83.40	
46	OKCE 125 NTR/2,2kW	1553	0.64	84.03	
47	Ohřívače OKHE ONE 80	1502	0.62	84.65	
48	NADO 750 l	1483	0.61	85.26	
49	NAD 500 l	1437	0.59	85.85	
50	OKHE 100	1386	0.57	86.42	
51	OKC 200 NTRR/BP	1379	0.57	86.99	
52	Ohřívače OKHE ONE 100	1366	0.56	87.55	
53	OKHE 80	1347	0.55	88.10	
54	OKHE 125 SMART	1324	0.54	88.65	
55	OKCE 160 S/2,2kW	1277	0.52	89.17	
56	OKCEV 200	1222	0.50	89.68	
57	OKH 100 NTR/HV	1200	0.49	90.17	
58	OKC 400 - NTRR/ SOL, NTR/HP, NTRR/HP/SOL	1195	0.49	90.66	
59	OKHE 160 SMART	1182	0.49	91.15	
60	Ohřívače OKHE ONE 120	1117	0.46	91.61	
61	OKC 100/1m2	1109	0.46	92.06	
62	OKC 200 NTR	1082	0.44	92.51	
63	OKC 250 NTRR/SOL	1064	0.44	92.94	
64	OKC 500 NTR,R/BP	1002	0.41	93.36	
65	OKCE 100 S/2,2kW	984	0.40	93.76	
66	OKC 300 NTR/BP	944	0.39	94.15	
67	Ohřívače OKHE ONE 50	932	0.38	94.53	
68	OKC 300 NTRR/BP	891	0.37	94.90	
69	OKHE 100 SMART	846	0.35	95.25	
70	NADO 1000 l	797	0.33	95.57	
71	OKC 125 NTR	735	0.30	95.88	
72	OKCE 250 S/3-6kW	729	0.30	96.17	
73	OKC 250 NTR/BP	695	0.29	96.46	
74	OKCE 100 NTR/2,2kW	688	0.28	96.74	
75	OKC 500 - NTRR/ SOL, NTR/HP, NTRR/HP/SOL	682	0.28	97.02	
76	OKHE 80 SMART	676	0.28	97.30	
77	OKC 250 NTRR/BP	601	0.25	97.55	
78	OKCE 300 S/2,2 kW	601	0.25	97.80	
79	NAD 300 l	573	0.24	98.03	C
80	Ohřívače OKHE ONE 30	519	0.21	98.24	
81	OKC 200 NTRR	510	0.21	98.45	
82	OKC 400 NTR,R/BP	489	0.20	98.66	
83	OKCE 200 NTR/2,2kW	460	0.19	98.84	
84	OKCE 160 NTR/2,2kW	430	0.18	99.02	
85	OKC 200 NTRR/ HR 120	369	0.15	99.17	
86	OKC 100 NTR/Z	268	0.11	99.28	
87	OKC 125 NTR/Z	264	0.11	99.39	

88	OKC 160 NTR/Z	225	0.09	99.48	
89	OKC 80 NTR/Z	176	0.07	99.56	
90	OKC 200 NTR/Z	172	0.07	99.63	
91	Nádoba v izolaci OKC 60 NTR	144	0.06	99.69	
92	UKV 300	142	0.06	99.74	
93	OKC 250 NTR	104	0.04	99.79	
94	OKH 160 NTR	104	0.04	99.83	
95	UKV 500	102	0.04	99.87	
96	OKC 250 NTRR	74	0.03	99.90	
97	Nádoba v izolaci OKC 100 NTR	72	0.03	99.93	
98	NADO 400l	65	0.03	99.96	
99	NADO 300 l	40	0.02	99.98	
100	OKCE 200 S/3-6kW	38	0.02	99.99	
101	OKCE 300 S 3-6 kW	20	0.01	100.00	
102	OKCE 300 NTRR/3-6 kW	1	0.00		
103	NAD 400l	1	0.00		
104	OKCE 250 S/2,2kW	0	0.00		
105	OKCE 160 S/3-6kW	0	0.00		
106	Mnoblock 100	0	0.00		
107	200 LTS - TOP	0	0.00		
108	OKCE 250 NTR/2,2kW	0	0.00		
109	OKCE 200 NTRR/2,2kW	0	0.00		
110	OKCE 250 NTRR/2,2kW	0	0.00		
111	OKC 100 NTR/BP	0	0.00		
112	OKC 125 NTR/BP	0	0.00		
113	OKCV 125 NTR	0	0.00		
114	OKCV 180 NTR	0	0.00		D
115	OKCV 200 NTR	0	0.00		
116	300 LTS - TOP	0	0.00		
117	OKCE 300 NTR/2,2 kW	0	0.00		
118	OKCE 300 NTR/3-6 kW	0	0.00		
119	OKCE 300 NTRR/2,2 kW	0	0.00		
120	OKC 300 NTR/1Mpa	0	0.00		
121	OKC 300 NTRR/1MPa	0	0.00		
122	OKC 200 NTR/SOL	0	0.00		
123	OKH 100 NTR	0	0.00		
124	OKH 125 NTR	0	0.00		
125	Nádoba v izolaci OKC 40 NTR	0	0.00		
126	Nádoba v izolaci OKC 80 NTR	0	0.00		

Attachment number 2: Average Time

Driver A

S.No	Loading time (min) Drazice	Transport time D-W (min)	Unloading time @ W (min)	Transport Time W-L (min)
1	23	9	12	4
2	26	10	13	2
3	24	8	15	2
4	21	7	13	2
5	25	7	15	2
6	30	8	12	4
7	27	10	16	2
8	22	9	14	2
9	20	7	13	2
10	26	8	15	4
11	27	9	12	2
12	28	7	17	2
13	25	8	13	2
14	28	10	16	2
15	25	8	18	2
Average	25.13	8.33	14.27	2.4
Median	25.00	8.00	14.00	2.00
Mode	25.00	8.00	13.00	2.00
Variance	7.70	1.24	3.64	0.69

Driver B

S.No	Loading time Lustenice (min)	Transport Time L-W (min)	Unloading time @ W (min)	Transport time W - D (min)
1	20	2	10	7
2	19	2	11	8
3	18	4	12	10
4	19	2	13	8
5	20	2	14	9
6	21	2	11	7
7	20	4	12	11
8	19	2	13	9
9	21	2	12	7
10	19	4	11	8
11	20	2	14	9
12	21	2	13	10
13	18	2	12	8
14	21	2	10	7
15	19	2	14	10
Average	19.67	2.4	12.13	8.53
Median	20	2	12	8
Mode	19	2	12	7
Variance	1.10	0.69	1.84	1.70

Attachment number 3: Snapshot of the day

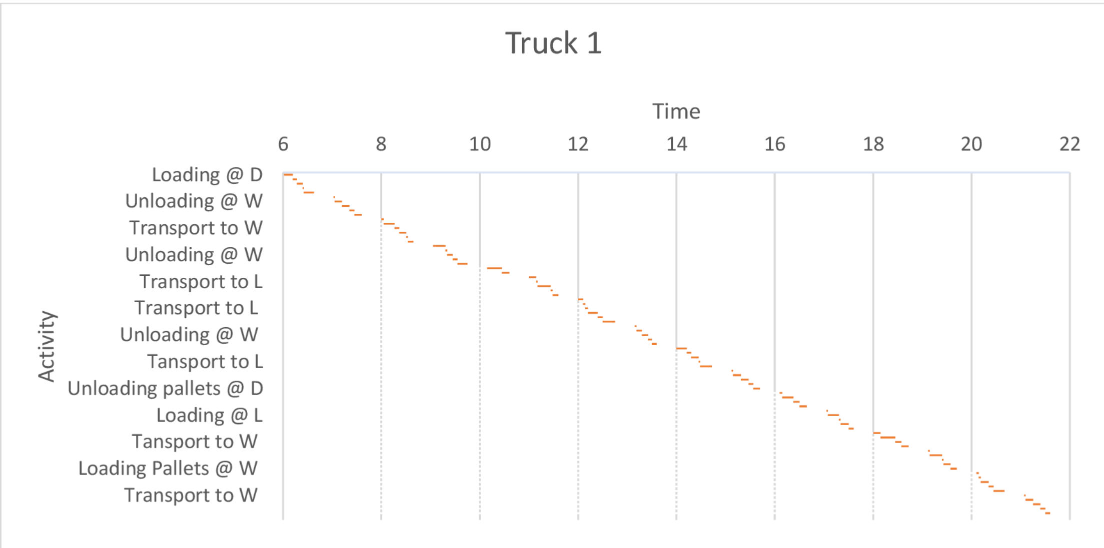
Real time	Time by stopwatch			Category	1	2	3	4	5	6	7
	From	To	Difference		LD	ULD	TLW	TDW	GAS	D	Breaks
06:00	00:00	00:23	00:23	1	00:23						
06:23	00:23	00:31	00:08	4				00:08			
06:31	00:31	00:45	00:14	2		00:14					
06:45	00:45	00:47	00:02	3			00:02				
06:47	00:47	01:10	00:23	1	00:23						
07:10	01:10	01:12	00:02	3			00:02				
07:12	01:12	01:26	00:14	2		00:14					
07:26	01:26	01:41	00:15	1	00:15						
07:41	01:41	01:49	00:08	4				00:08			
07:49	01:49	02:00	00:11	2		00:11					
08:00	02:00	02:05	00:05	7							00:05
08:05	02:05	02:28	00:23	1	00:23						
08:28	02:28	02:36	00:08	4				00:08			
08:36	02:36	02:50	00:14	2		00:14					
08:50	02:50	02:52	00:02	3			00:02				
08:52	02:52	03:05	00:13	6						00:13	
09:05	03:05	03:28	00:23	1	00:23						
09:28	03:28	03:30	00:02	3			00:02				
09:30	03:30	03:44	00:14	2		00:14					
09:44	03:44	03:52	00:09	4				00:08			
09:52	03:52	04:15	00:23	1	00:23						
10:15	04:15	04:45	00:30	7							00:30
10:45	04:45	04:53	00:08	4				00:08			
10:53	04:53	05:07	00:14	2		00:14					
11:07	05:07	05:10	00:03	3			00:03				
11:10	05:10	05:33	00:23	1	00:23						
11:33	05:33	05:35	00:02	3			00:02				
11:35	05:35	05:50	00:15	2		00:15					
11:50	05:50	06:00	00:10	4				00:10			
12:00	06:00	06:05	00:05	7							00:05
12:05	06:05	06:20	00:15	1	00:15						
12:20	06:20	06:22	00:02	3			00:02				
12:22	06:22	06:35	00:13	7							
12:35	06:35	06:50	00:15	2		00:13			00:15		
12:50	06:50	07:13	00:23	1	00:23						
01:13	07:13	07:15	00:02	3			00:02				
01:15	07:15	07:30	00:15	2		00:15					
01:30	07:30	07:38	00:08	4				00:08			
01:38	07:38	07:50	00:12	1	00:12						
01:50	07:50	08:00	00:10	7							00:10

Attachment number 4: Current schedule for Truck 1

Activity	Shift	Task allocated to	Daily activity	Time	Start	End	Task timing (min)
1	1	Driver 1	Loading @ D	06:00 - 06:20	6:00	06:20	20
2	1	Driver 1	Transport to W	06:20 - 06:28	06:20	06:28	8
3	1	Driver 1	Unloading @ W	06:28 - 06:40	06:28	06:40	12
4	1	Driver 1	Tansport to L	06:40 - 06:42	06:40	06:42	2
5	1	Driver 1	Loading @ L	06:42 - 07:03	06:42	07:03	21
6	1	Driver 1	Transport to W	07:03 - 07:05	07:03	07:05	2
7	1	Driver 1	Unloading @ W	07:05 - 07:20	07:05	07:20	15
8	1	Driver 1	Loading of pallets	07:20 - 07:35	07:20	07:35	15
9	1	Driver 1	Transport to D	07:35 - 07:45	07:35	07:45	10
10	1	Driver 1	Unloading pallets @ D	07:45 - 08:00	07:45	08:00	15
11	1	Driver 1	Break 1	08:00 - 08:05	08:00	08:05	5
12	1	Driver 1	Loading @ D	08:05 - 08:27	08:05	08:27	22
13	1	Driver 1	Transport to W	08:27 - 08:36	08:27	08:36	9
14	1	Driver 1	Unloading @ w	08:36 - 08:50	08:36	08:50	14
15	1	Driver 1	Transport to L	08:50 - 08:54	08:50	08:54	4
16	1	Driver 1	Delay @ L	08:54 - 09:05	08:54	09:05	11
17	1	Driver 1	Loading @ L	09:07 - 09:30	09:05	09:30	25
18	1	Driver 1	Transport to W	09:30 - 09:34	09:30	09:34	4
19	1	Driver 1	Unloading @ W	09:34 - 09:45	09:34	09:45	11
20	1	Driver 1	Tansport to D	09:47 - 09:55	09:45	09:55	10
21	1	Driver 1	Loading @ D	09:55 - 10:15	09:55	10:15	20
22	1	Driver 1	Lunch Break	10:15 - 10:45	10:15	10:45	30
24	1	Driver 1	Tansport to W	10:45 - 11:00	10:45	11:00	15
25	1	Driver 1	Unloading @ W	11:00 - 11:15	11:00	11:15	15
26	1	Driver 1	Transport to L	11:15 - 11:18	11:15	11:18	3
27	1	Driver 1	Loading @ L	11:18 - 11:44	11:18	11:44	26
28	1	Driver 1	Transport to W	11:44 - 11:48	11:44	11:48	4
29	1	Driver 1	Unloading @ W	11:48 - 12:00	11:48	12:00	12
30	1	Driver 1	Loading Pallets @ W	12:00 - 12:10	12:00	12:10	10
31	1	Driver 1	Break 3	12:10 - 12:15	12:10	12:15	5
32	1	Driver 1	Transport to L	12:15 - 12:20	12:15	12:20	5
33	1	Driver 1	Unloading pallets @ L	12:20 - 12:40	12:20	12:40	20
38	1	Driver 1	Delay @ L	12:40 - 12:50	12:40	12:50	10
34	1	Driver 1	Loading @ L	12:50 -01:15	12:50	13:15	25
35	1	Driver 1	Transport to W	01:15 - 01:19	13:15	13:19	4
36	1	Driver 1	Delay @ W	01:19 - 01:30	13:19	13:30	11
37	1	Driver 1	Unloading @ W	01:30 - 01:42	13:30	13:42	12
38	1	Driver 1	Transport to D	01:42 - 01:50	13:42	13:50	8
39	1	Driver 1	Break 4	01:50 - 02:00	13:50	14:00	10
			Shift 1 END				
40	2	Driver 3	Loading @ D	02:00 - 02:21	14:00	14:21	21
41	2	Driver 3	Transport to W	02:21 - 02:30	14:21	14:30	9
42	2	Driver 3	Unloading @ W	02:30 - 02:45	14:30	14:45	15
43	2	Driver 3	Tansport to L	02:45 - 02:48	14:45	14:48	3
44	2	Driver 3	Loading @ L	02:48 - 03:12	14:48	15:12	24
45	2	Driver 3	Transport to W	03:12 - 03:15	15:12	15:15	3
46	2	Driver 3	Unloading @ W	03:15 - 03:31	15:15	15:31	16
47	2	Driver 3	Loading of pallets	03:31 - 03:47	15:31	15:47	16
48	2	Driver 3	Transport to D	03:47 - 03:56	15:47	15:56	9
49	2	Driver 3	Unloading pallets @ D	03:56 - 04:10	15:56	16:10	14
50	2	Driver 3	Break 1	04:10 - 04:15	16:10	16:15	5

51	2	Driver 3	Loading @ D	04:15 - 04:38	16:15	16:38	23
52	2	Driver 3	Transport to W	04:38 - 04:50	16:38	16:50	12
53	2	Driver 3	Unloading @ w	04:50 - 05:05	16:50	17:05	15
54	2	Driver 3	Transport to L	05:05 - 05:08	17:05	17:08	3
55	2	Driver 3	Loading @ L	05:08 - 05:30	17:08	17:30	22
56	2	Driver 3	Transport to W	05:30 - 05:34	17:30	17:34	4
57	2	Driver 3	Unloading @ W	05:34 - 05:50	17:34	17:50	16
58	2	Driver 3	Tansport to D	05:50 - 06:00	17:50	18:00	10
59	2	Driver 3	Loading @ D	06:00 - 06:15	18:00	18:15	15
60	2	Driver 3	Lunch Break	06:15 - 06:45	18:15	18:45	30
61	2	Driver 3	Tansport to W	06:45 - 06:57	18:45	18:57	12
62	2	Driver 3	Unloading @ W	06:57 - 07:12	18:57	19:12	15
63	2	Driver 3	Transport to L	07:12 - 07:15	19:12	19:15	3
64	2	Driver 3	Loading @ L	07:15 - 07:40	19:15	19:40	25
65	2	Driver 3	Transport to W	07:40 - 07:43	19:40	19:43	3
66	2	Driver 3	Unloading @ W	07:43 - 07:57	19:43	19:57	14
67	2	Driver 3	Loading Pallets @ W	07:57 - 08:10	19:57	20:10	13
68	2	Driver 3	Break 3	08:10 - 08:15	20:10	20:15	5
69	2	Driver 3	Transport to L	08:15 - 08:19	20:15	20:19	4
70	2	Driver 3	Unloading pallets @ L	08:19 - 08:35	20:19	20:35	16
71	2	Driver 3	Delay @ L	08:35 - 08:45	20:35	20:45	10
72	2	Driver 3	Loading @ L	08:45 - 09:07	20:45	21:07	22
73	2	Driver 3	Transport to W	09:07 - 09:10	21:07	21:10	3
74	2	Driver 3	Delay @ W	09:10 - 09:25	21:10	21:25	15
75	2	Driver 3	Unloading @ W	09:25 - 09:40	21:25	21:40	15
76	2	Driver 3	Transport to D	09:40 - 09:50	21:40	21:50	10
77	2	Driver 3	Break 4	09:50 - 10:00	21:50	22:00	10

Attachment number 5: Gantt chart of Current schedule Truck 1

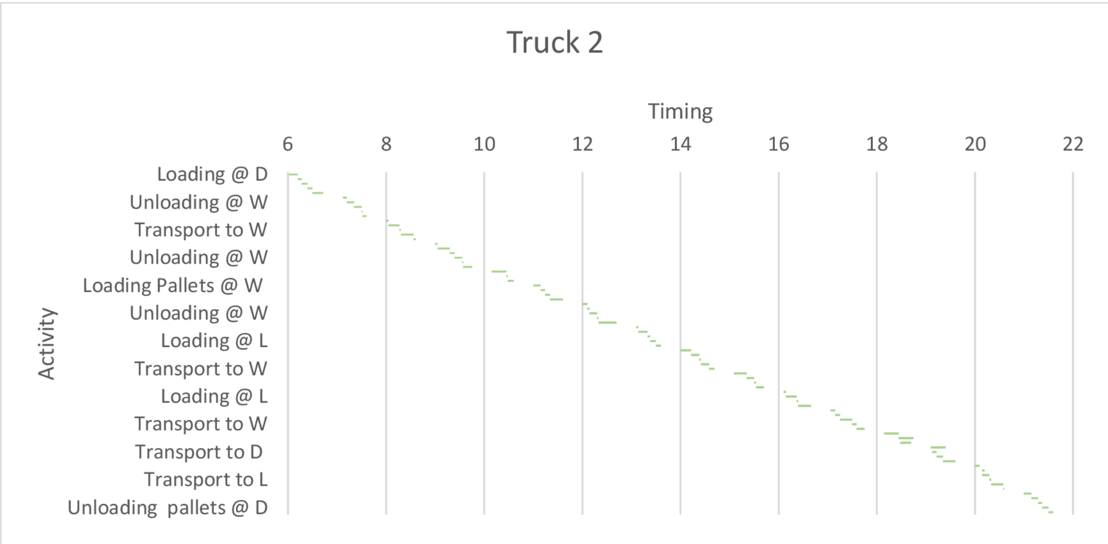


Attachment number 6: Current schedule for Truck 2

Activity	Shift	Task allocated to	Daily activity	IN	OUT	Task timing (hr)
1	1	Driver 2	Loading @ D	6	6.20	0.20
2	1	Driver 2	Transport to W	6.20	6.28	0.08
3	1	Driver 2	Unloading @ W	6.28	6.40	0.12
4	1	Driver 2	Tansport to D	6.40	6.50	0.10
5	1	Driver 2	Loading @ D	6.50	7.12	0.22
6	1	Driver 2	Transport to W	7.12	7.20	0.08
7	1	Driver 2	Unloading @ W	7.20	7.35	0.15
8	1	Driver 2	Loading of pallets	7.35	7.50	0.15
9	1	Driver 2	Transport to L	7.50	7.52	0.02
10	1	Driver 2	Unloading pallets @ L	7.52	8.00	0.08
11	1	Driver 2	Break 1	8.00	8.05	0.05
12	1	Driver 2	Loading @ L	8.05	8.27	0.22
13	1	Driver 2	Transport to W	8.27	8.30	0.03
14	1	Driver 2	Unloading @ w	8.30	8.56	0.26
15	1	Driver 2	Transport to D	8.56	9.00	0.04
16	1	Driver 2	Delay @ D	9.00	9.05	0.05
17	1	Driver 2	Loading @ D	9.05	9.30	0.25
18	1	Driver 2	Transport to W	9.30	9.40	0.10
19	1	Driver 2	Unloading @ W	9.40	9.55	0.15
20	1	Driver 2	Tansport to L	9.55	9.57	0.02
21	1	Driver 2	Loading @ L	9.57	10.15	0.18
22	1	Driver 2	Lunch Break	10.15	10.45	0.30
23	1	Driver 2	Tansport to W	10.45	10.48	0.03
24	1	Driver 2	Unloading @ W	10.48	11.00	0.12
25	1	Driver 2	Loading Pallets @ W	11.00	11.15	0.15
26	1	Driver 2	Transport to D	11.15	11.24	0.09
27	1	Driver 2	Unloading pallets @ D	11.24	11.34	0.10
28	1	Driver 2	Loading @ D	11.34	12.00	0.26
29	1	Driver 2	Transport to W	12.00	12.10	0.10
30	1	Driver 2	Break 3	12.10	12.15	0.05
31	1	Driver 2	Unloading @ W	12.15	12.30	0.15
32	1	Driver 2	Transport to L	12.30	12.33	0.03
33	1	Driver 2	Loading @ L	12.33	13.10	0.37
34	1	Driver 2	Transport to W	13.10	13.14	0.04
35	1	Driver 2	Unloading @ W	13.14	13.33	0.19
36	1	Driver 2	Transport to L	13.33	13.38	0.05
37	1	Driver 2	Loading @ L	13.38	13.50	0.12
38	1	Driver 2	Break 4	13.50	14.00	0.10
			Shift 1 END			
39	2	Driver 4	Transport to W	14.00	14.22	0.22
40	2	Driver 4	Unloading @ W	14.22	14.38	0.16
41	2	Driver 4	Tansport to D	14.38	14.42	0.04
42	2	Driver 4	Loading @ D	14.42	14.58	0.16
43	2	Driver 4	Transport to W	14.58	15.09	0.11
44	2	Driver 4	Unloading @ W	15.09	15.35	0.26
45	2	Driver 4	Loading of pallets	15.35	15.50	0.15
46	2	Driver 4	Transport to L	15.50	15.54	0.04
47	2	Driver 4	Unloading pallets @ L	15.54	16.10	0.16
48	2	Driver 4	Break 1	16.10	16.15	0.05

49	2	Driver 4	Loading @ L	04:15 - 04:37	16:15	16:37	22
50	2	Driver 4	Transport to W	04:37 - 04:40	16:37	16:40	3
51	2	Driver 4	Unloading @ w	04:40 - 05:06	16:40	17:06	26
52	2	Driver 4	Transport to D	05:06 - 05:15	17:06	17:15	9
53	2	Driver 4	Delay @ D	05:15 - 05:25	17:15	17:25	10
54	2	Driver 4	Loading @ D	05:25 - 05:50	17:25	17:50	25
55	2	Driver 4	Transport to W	05:50 - 05:59	17:50	17:59	9
56	2	Driver 4	Unloading @ W	05:59 - 06:15	17:59	18:15	16
57	2	Driver 4	Lunch Break	06:15 - 06:45	18:15	18:45	30
58	2	Driver 4	Tansport to L	06:45 - 06:48	18:45	18:48	3
59	2	Driver 4	Loading @ L	06:48 - 07:10	18:48	19:10	22
60	2	Driver 4	Tansport to W	07:10 - 07:13	19:10	19:13	3
61	2	Driver 4	Transport to D	07:13 - 07:22	19:13	19:22	9
62	2	Driver 4	Unloading pallets @ D	07:22 - 07:35	19:22	19:35	13
63	2	Driver 4	Loading @ D	07:35 - 08:00	19:35	20:00	25
64	2	Driver 4	Transport to W	08:00 - 08:10	20:00	20:10	10
65	2	Driver 4	Break 3	08:10 - 08:15	20:10	20:15	5
66	2	Driver 4	Unloading @ W	08:15 - 08:30	20:15	20:30	15
67	2	Driver 4	Transport to L	08:30 - 08:33	20:30	20:33	3
68	2	Driver 4	Loading @ L	08:33 -08:58	20:33	20:58	25
69	2	Driver 4	Transport to W	08:58 - 09:00	20:58	21:00	2
70	2	Driver 4	Unloading @ W	09:00 - 09:15	21:00	21:15	15
71	2	Driver 4	Loading pallets	09:15 - 09:29	21:15	21:29	14
72	2	Driver 4	Transport pallets to D	09:29 - 09:37	21:29	21:37	8
73	2	Driver 4	Unloading pallets @ D	09:37 - 09:50	21:37	21:50	13
74	2	Driver 4	Break 4	09:50 - 10:00	21:50	22:00	10
			Shift end				

Attachment number 7: Gantt Chart for current schedule truck 2



Attachment number 8: New schedule for Truck 2

Activity	Shift	Task allocated	Daily activity	Start	End	Task timing (min)
1	1	Driver 2	Loading @ D	06:00	06:30	30.00
2	1	Driver 2	Transport to W	06:30	06:38	8.00
3	1	Driver 2	Unloading @ w	06:38	06:58	20.00
4	1	Driver 2	Transport to D	06:58	07:06	8.00
5	1	Driver 2	Loading @ D	07:06	07:36	30.00
6	1	Driver 2	Transport to W	07:36	07:44	8.00
7	1	Driver 2	Unloading @ w	07:44	08:00	16.00
8	1	Driver 2	Break 1	08:00	08:05	5.00
9	1	Driver 2	Loading pallets	08:05	08:20	15.00
10	1	Driver 2	transport to L	08:20	08:22	2.00
11	1	Driver 2	Unloading Pallets	08:22	08:35	13.00
12	1	Driver 2	Loading @ L	08:35	09:05	30.00
13	1	Driver 2	Transport to W	09:05	09:07	2.00
14	1	Driver 2	Unloading @ w	09:07	09:27	20.00
15	1	Driver 2	Transport to L	09:27	09:30	3.00
16	1	Driver 2	Loading @ L	09:30	10:00	30.00
17	1	Driver 2	Transport to W	10:00	10:02	2.00
18	1	Driver 2	Unloading @ W	10:02	10:15	13.00
19	1	Driver 2	Lunch Break	10:15	10:45	30.00
20	1	Driver 2	Transport to D	10:45	10:53	8.00
21	1	Driver 2	Loading @ D	10:53	11:23	30.00
22	1	Driver 2	Transport to W	11:23	11:30	7.00
23	1	Driver 2	Unloading @ W	11:30	11:50	20.00
24	1	Driver 2	Transport to D	11:50	12:00	10.00
25	1	Driver 2	Loading @ D	12:00	12:10	10.00
26	1	Driver 2	Break 3	12:10	12:15	5.00
27	1	Driver 2	Loading @ D	12:15	12:30	15.00
28	1	Driver 2	Transport to W	12:30	12:38	8.00
29	1	Driver 2	Unloading @ W	12:38	12:55	17.00
30	1	Driver 2	Transport to L	12:55	12:57	2.00
31	1	Driver 2	Loading @ L	12:57	13:27	30.00
32	1	Driver 2	Transport to W	13:27	13:29	2.00
33	1	Driver 2	Unloading @ W	13:29	13:42	13.00
34	1	Driver 2	Transport to D	13:42	13:50	8.00
35	1	Driver 2	Bread 4	13:50	14:00	10.00
Shift ends						

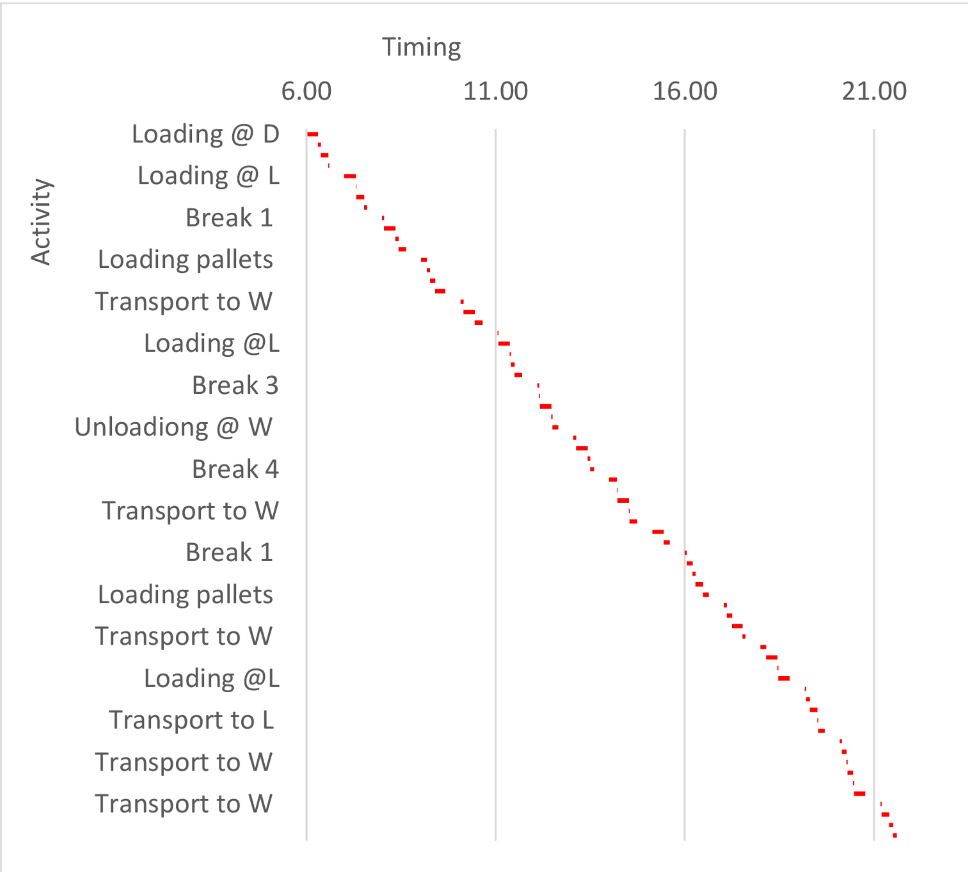
36	1	Driver 4	Loading @ D	14:00	14:30	30.00
37	1	Driver 4	Transport to W	14:30	14:38	8.00
38	1	Driver 4	Unloading @ w	14:38	14:58	20.00
39	1	Driver 4	Transport to D	14:58	15:06	8.00
40	1	Driver 4	Loading @ D	15:06	15:36	30.00
41	1	Driver 4	Transport to W	15:36	15:44	8.00
42	1	Driver 4	Unloading @ w	15:44	16:00	16.00
43	1	Driver 4	Break 1	16:00	16:05	5.00
44	1	Driver 4	Loading pallets	16:05	16:20	15.00
45	1	Driver 4	transport to L	16:20	16:22	2.00
46	1	Driver 4	Unloading Pallets	16:22	16:35	13.00
47	1	Driver 4	Loading @ L	16:35	17:05	30.00
48	1	Driver 4	Transport to W	17:05	17:07	2.00
49	1	Driver 4	Unloading @ w	17:07	17:27	20.00
50	1	Driver 4	Transport to L	17:27	17:30	3.00
51	1	Driver 4	Loading @ L	17:30	18:00	30.00
52	1	Driver 4	Transport to W	18:00	18:02	2.00
53	1	Driver 4	Unloading @ W	18:02	18:15	13.00
54	1	Driver 4	Lunch Break	18:15	18:45	30.00
55	1	Driver 4	Transport to D	18:45	18:53	8.00
56	1	Driver 4	Loading @ D	18:53	19:23	30.00
57	1	Driver 4	Transport to W	19:23	19:30	7.00
58	1	Driver 4	Unloading @ W	19:30	19:50	20.00
59	1	Driver 4	Transport to D	19:50	20:00	10.00
60	1	Driver 4	Loading @ D	20:00	20:10	10.00
61	1	Driver 4	Break 3	20:10	20:15	5.00
62	1	Driver 4	Loading @ D	20:15	20:30	15.00
63	1	Driver 4	Transport to W	20:30	20:38	8.00
64	1	Driver 4	Unloading @ W	20:38	20:55	17.00
65	1	Driver 4	Transport to L	20:55	20:57	2.00
66	1	Driver 4	Loading @ L	20:57	21:27	30.00
67	1	Driver 4	Transport to W	21:27	21:29	2.00
68	1	Driver 4	Unloading @ W	21:29	21:42	13.00
69	1	Driver 4	Transport to D	21:42	21:50	8.00
70	1	Driver 4	Bread 4	21:50	22:00	10.00
Shift ends						

Attachment number 9: New schedule testing result 3 with full schedule for Truck 1

Activity	Shift	Task allocated	Daily activity	Start	End	Task timing (min)
1	1	Driver 1	Loading @ D	06:00	06:30	30.00
2	1	Driver 1	Transport to W	06:30	06:38	8.00
3	1	Driver 1	Unloading @ w	06:38	06:58	20.00
4	1	Driver 1	Transport to L	06:58	07:00	2.00
5	1	Driver 1	Loading @ L	07:00	07:30	30.00
6	1	Driver 1	Transport to W	07:30	07:32	2.00
7	1	Driver 1	Unloading @ W	07:32	07:52	20.00
8	1	Driver 1	Transport to D	07:52	08:00	8.00
9	1	Driver 1	Break 1	08:00	08:05	5.00
10	1	Driver 1	Loading @ D	08:05	08:35	30.00
11	1	Driver 1	Transport to W	08:35	08:43	8.00
12	1	Driver 1	Unloading @ W	08:43	09:03	20.00
13	1	Driver 1	Loading pallets	09:03	09:18	15.00
14	1	Driver 1	Transport to D	09:18	09:26	8.00
15	1	Driver 1	Unloading pallets	09:26	09:40	14.00
16	1	Driver 1	Loading @ D	09:40	10:07	27.00
17	1	Driver 1	Transport to W	10:07	10:15	8.00
18	1	Driver 1	Lunch Break	10:15	10:45	30.00
19	1	Driver 1	Unloading @ w	10:45	11:05	20.00
20	1	Driver 1	Transport to L	11:05	11:07	2.00
21	1	Driver 1	Loading @L	11:07	11:37	30.00
22	1	Driver 1	Transport to W	11:37	11:40	3.00
23	1	Driver 1	Fuel refill	11:40	11:50	10.00
24	1	Driver 1	Unloading @ W	11:50	12:10	20.00
25	1	Driver 1	Break 3	12:10	12:15	5.00
26	1	Driver 1	Transport to L	12:15	12:17	2.00
27	1	Driver 1	Loading @ L	12:17	12:47	30.00
28	1	Driver 1	Transport to W	12:47	12:50	3.00
29	1	Driver 1	Unloadiong @ W	12:50	13:05	15.00
30	1	Driver 1	Transport to D	13:05	13:13	8.00
31	1	Driver 1	Loading @ D	13:13	13:43	30.00
32	1	Driver 1	Transport to W	13:43	13:50	7.00
33	1	Driver 1	Break 4	13:50	14:00	10.00
Shift ends						
34	2	Driver 3	Unloading @ w	14:00	14:20	20.00
35	2	Driver 3	Transport to L	15:00	14:22	2.00
36	2	Driver 3	Loading @ L	16:00	14:52	30.00
37	2	Driver 3	Transport to W	17:00	14:54	2.00
38	2	Driver 3	Unloading @ W	18:00	15:14	20.00
39	2	Driver 3	Transport to D	19:00	15:44	30.00
40	2	Driver 3	Loading @ D	20:00	16:00	16.00
41	2	Driver 3	Break 1	21:00	16:05	5.00
42	2	Driver 3	Loading @ D	22:00	16:20	15.00
43	2	Driver 3	Transport to W	23:00	16:28	8.00
44	2	Driver 3	Unloading @ W	00:00	16:48	20.00
45	2	Driver 3	Loading pallets	01:00	17:03	15.00
46	2	Driver 3	Transport to D	02:00	17:11	8.00
47	2	Driver 3	Unloading pallets	03:00	17:25	14.00
48	2	Driver 3	Loading @ D	04:00	17:52	27.00
49	2	Driver 3	Transport to W	05:00	18:00	8.00
50	2	Driver 3	Unloading @ W	06:00	18:15	15.00
51	2	Driver 3	Lunch Break	07:00	18:45	30.00

52	2	Driver 3	Transport to L	08:00	18:47	2.00
53	2	Driver 3	Loading @L	09:00	19:17	30.00
54	2	Driver 3	Transport to W	10:00	19:20	3.00
55	2	Driver 3	Fuel refill	11:00	19:30	10.00
56	2	Driver 3	Unloading @ W	12:00	19:50	20.00
57	2	Driver 3	Transport to L	13:00	19:52	2.00
58	2	Driver 3	Loading @ L	14:00	20:10	18.00
59	2	Driver 3	Break 3	15:00	20:15	5.00
60	2	Driver 3	Loading @ L	16:00	20:27	12.00
61	2	Driver 3	Transport to W	17:00	20:30	3.00
62	2	Driver 3	Unloadiong @ W	18:00	20:45	15.00
63	2	Driver 3	Transport top L	19:00	20:47	2.00
64	2	Driver 3	Loading @ L	20:00	21:17	30.00
65	2	Driver 3	Transport to W	21:00	21:20	3.00
66	2	Driver 3	Unloading @ W	22:00	21:40	20.00
67	2	Driver 3	Transport to D	23:00	21:50	10.00
68	2	Driver 3	Break 4	21:50	22:00	10.00
Shift ends						

Attachment number 10: Gantt chart for new schedule testing result 3 with full schedule for Truck 1



Attachment number 11: New schedule testing result 3 for truck 2

Activity	Shift	Task allocated	Daily activity	Start	End	Task timing (min)
1	1	Driver 2	Loading @ D	06:00	06:30	30.00
2	1	Driver 2	Transport to W	06:30	06:38	8.00
3	1	Driver 2	Unloading @ w	06:38	06:58	20.00
4	1	Driver 2	Transport to D	06:58	07:06	8.00
5	1	Driver 2	Loading @ D	07:06	07:36	30.00
6	1	Driver 2	Transport to W	07:36	07:44	8.00
7	1	Driver 2	Unloading @ w	07:44	08:00	16.00
8	1	Driver 2	Break 1	08:00	08:05	5.00
9	1	Driver 2	Loading pallets	08:05	08:20	15.00
10	1	Driver 2	transport to L	08:20	08:22	2.00
11	1	Driver 2	Unloading Pallets	08:22	08:35	13.00
12	1	Driver 2	Loading @ L	08:35	09:05	30.00
13	1	Driver 2	Transport to W	09:05	09:07	2.00
14	1	Driver 2	Unloading @ w	09:07	09:27	20.00
15	1	Driver 2	Transport to L	09:27	09:30	3.00
16	1	Driver 2	Loading @ L	09:30	10:00	30.00
17	1	Driver 2	Transport to W	10:00	10:02	2.00
18	1	Driver 2	Unloading @ W	10:02	10:15	13.00
19	1	Driver 2	Lunch Break	10:15	10:45	30.00
20	1	Driver 2	Transport to D	10:45	10:53	8.00
21	1	Driver 2	Loading @ D	10:53	11:23	30.00
22	1	Driver 2	Transport to W	11:23	11:30	7.00
23	1	Driver 2	Unloading @ W	11:30	11:50	20.00
24	1	Driver 2	Transport to D	11:50	12:00	10.00
25	1	Driver 2	Loading @ D	12:00	12:10	10.00
26	1	Driver 2	Break 3	12:10	12:15	5.00
27	1	Driver 2	Loading @ D	12:15	12:30	15.00
28	1	Driver 2	Transport to W	12:30	12:38	8.00
29	1	Driver 2	Unloading @ W	12:38	12:55	17.00
30	1	Driver 2	Transport to L	12:55	12:57	2.00
31	1	Driver 2	Loading @ L	12:57	13:27	30.00
32	1	Driver 2	Transport to W	13:27	13:29	2.00
33	1	Driver 2	Unloading @ W	13:29	13:42	13.00
34	1	Driver 2	Transport to D	13:42	13:50	8.00
35	1	Driver 2	Bread 4	13:50	14:00	10.00
Shift ends						

36	1	Driver 4	Loading @ D	14:00	14:30	30.00
37	1	Driver 4	Transport to W	14:30	14:38	8.00
38	1	Driver 4	Unloading @ w	14:38	14:58	20.00
39	1	Driver 4	Transport to D	14:58	15:06	8.00
40	1	Driver 4	Loading @ D	15:06	15:36	30.00
41	1	Driver 4	Transport to W	15:36	15:44	8.00
42	1	Driver 4	Unloading @ w	15:44	16:00	16.00
43	1	Driver 4	Break 1	16:00	16:05	5.00
44	1	Driver 4	Loading pallets	16:05	16:20	15.00
45	1	Driver 4	transport to L	16:20	16:22	2.00
46	1	Driver 4	Unloading Pallets	16:22	16:35	13.00
47	1	Driver 4	Loading @ L	16:35	17:05	30.00
48	1	Driver 4	Transport to W	17:05	17:07	2.00
49	1	Driver 4	Unloading @ w	17:07	17:27	20.00
50	1	Driver 4	Transport to L	17:27	17:30	3.00
51	1	Driver 4	Loading @ L	17:30	18:00	30.00
52	1	Driver 4	Transport to W	18:00	18:02	2.00
53	1	Driver 4	Unloading @ W	18:02	18:15	13.00
54	1	Driver 4	Lunch Break	18:15	18:45	30.00
55	1	Driver 4	Transport to D	18:45	18:53	8.00
56	1	Driver 4	Loading @ D	18:53	19:23	30.00
57	1	Driver 4	Transport to W	19:23	19:30	7.00
58	1	Driver 4	Unloading @ W	19:30	19:50	20.00
59	1	Driver 4	Transport to D	19:50	20:00	10.00
60	1	Driver 4	Loading @ D	20:00	20:10	10.00
61	1	Driver 4	Break 3	20:10	20:15	5.00
62	1	Driver 4	Loading @ D	20:15	20:30	15.00
63	1	Driver 4	Transport to W	20:30	20:38	8.00
64	1	Driver 4	Unloading @ W	20:38	20:55	17.00
65	1	Driver 4	Transport to L	20:55	20:57	2.00
66	1	Driver 4	Loading @ L	20:57	21:27	30.00
67	1	Driver 4	Transport to W	21:27	21:29	2.00
68	1	Driver 4	Unloading @ W	21:29	21:42	13.00
69	1	Driver 4	Transport to D	21:42	21:50	8.00
70	1	Driver 4	Bread 4	21:50	22:00	10.00
Shift ends						

Attachment number 12: Gantt chart for new schedule test result 3