Czech University of Life Sciences Prague

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Master's Thesis

Optimization of the transportation routes between the flower company and its clients.

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Faculty of Economics and Management

DIPLOMA THESIS ASSIGNMENT

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Economics and Management

Thesis title

Optimization of transportation routes between flower company and its clients

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Objectives of thesis

The objective of this diploma thesis is to optimize the transportation routes for the local flower producer company "Tulip", aiming to find the most efficient routes while aligning with the company's objectives. The optimization process will consider the capacity limitations of two different vehicle types and customers' specific requirements regarding the transported goods. The company aims to minimize overall costs, while simultaneously meeting the customers' needs and preferences. To address this challenge, the thesis will employ a suitable mathematical model based on linear programming. By analyzing and optimizing the transport routes using the specific approach, the thesis aims to provide practical recommendations to "Tulip" for implementing cost-effective and customer-centric transport operations.

Methodology

The work is divided into two parts- theoretical and practical.

The theoretical part will draw primarily from the relevant sources of literature – books and scientific papers. The practical part will then be used for calculations concerning the input data. This part will include calculations of the distances from the company to its customers, creating a mathematical model of the delivery problem, and computing different scenarios. Finally, the calculated variants are compared, and the company is presented with the best-found solution with a recommendation on further reducing costs.

The proposed extent of the thesis

70-80

Keywords

transportation, optimization, tulips, delivery

Recommended information sources

Bradley, Stephen P., Hax, Arnold A., and Magnanti, Thomas L. – Applied Mathematical Programming (2008)

Solomon, M. M. – Algorithms for the vehicle routing and scheduling problems with time window constraints. Operations Research, (1998), 352-254-265.

Toth, Paolo and Vigo, Daniele (Eds.) – Vehicle Routing: Problems, Methods, and Applications (2014) Winston, Wayne L. – Operations Research: Applications and Algorithms (2014)

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Prague on 12. 03. 2024

Declaration

I declare that I have worked on my master's thesis titled "Optimization Routes between flower company and its customers" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the master's thesis, I declare that the thesis does not break any copyrights.

In Prague on 30.03.24 ______________________________

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Optimization of the transportation routes between the flower company and its clients.

Abstract

The name of this diploma thesis is “Optimization of transportation routes between the flower company and the clients”. “Mother’s Day” harvest and “International Women's Day” harvest are two scenarios that were chosen for this diploma thesis due to the highest number of crops during a year. The goal of this diploma thesis is to design the routes for transporting flowers from the company “Tulip” to customers in the southern region of Russia. The optimization process will consider the capacity limitations of two different vehicle types and customers' specific requirements regarding the transported goods. The company aims to minimize overall costs while simultaneously meeting the customers' needs and preferences. The thesis will employ a suitable mathematical model based on linear programming to address this challenge.

The diploma thesis will be divided into two parts: theoretical and practical.

In the theoretical part, the basic concepts of the operational research related to the main topic will be discussed. The theoretical part will draw primarily from the relevant sources of literature - books and scientific papers.

This theoretical part will be followed by the practical part, which will include the usage of the software designed to resolve such cases followed by the implementation of the traveling salesman problem using the optimization model. After that, economic analyses will be performed, such as KPI calculations, according to the results. Finally, the calculated variants are compared, and the company is presented with the best-found solution with a recommendation on further reducing costs.

Keywords: Operational research, logistics, transportation problem, minimization of costs, optimization model, delivery, efficiency, traveling salesman problem, methods.

Optimalizace přepravních cest mezi květinovou společností a klienty

Abstrakt

Název této diplomové práce je "Optimalizace přepravních cest mezi květinovou společností a klienty". Pro tuto práci byly vybrány dva scénáře, „Den matek“ a „Mezinárodní den žen“, a to z důvodu nejvyššího výnosu v průběhu roku.

Cílem této diplomové práce je navrhnout trasy pro přepravu květin od společnosti "Tulip" k zákazníkům v jižní oblasti Ruska. Optimalizační proces zohlední kapacitní omezení dvou různých typů vozidel, specifické požadavky zákazníků na přepravované zboží. Cílem společnosti je minimalizovat celkové náklady a zároveň vyhovět potřebám a preferencím zákazníků. K řešení tohoto úkolu bude v práci použit vhodný matematický model založený na lineárním programování. Diplomová práce bude rozdělena na dvě části: teoretickou a praktickou.
V teoretické části budou diskutovány základní koncepty operačního výzkumu související s hlavním tématem. Teoretická část bude čerpat především z relevantních zdrojů literatury – knih a vědeckých prací.

Na tuto teoretickou část bude navazovat praktická část, která bude zahrnovat využití softwaru určeného k řešení takových případů, následuje implementace problému obchodního cestujícího pomocí optimalizačního modelu. V souladu s výsledky pak budou provedeny ekonomické analýzy, jako jsou výpočty klíčových ukazatelů výkonnosti (KPI). Nakonec budou vypočtené varianty porovnány a nalezené nejlepší řešení bude předloženo firmě s doporučením, jak dále snížit náklady.

Klíčová slova: Operační výzkum, logistika, dopravní problém, minimalizace nákladů, optimalizační model, dodávka, efektivita, problém cestujícího obchodníka, metody.

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Introduction

Is it common to wonder where the delivery is coming from? How did it arrive at its destination, how long did it take, and how difficult was it? Unfortunately, not. Most of the time, no one considers those factors; they are just accepted. In today's globalized world, route optimization is central to every company's accomplishment.
As most businesses are being customer-focused at this moment, what has been influenced by the "customer service revolution" that happened twenty-five years ago. Satisfaction of the customer is interconnected with the logistic concept, the way the company supply chain works influences whether the customer will get the order fast or not, with delays or without, and how much it would cost him. Those factors build relationships with the customer and therefore logistics is a very important field of any business. However, many companies consider logistics as something pricy, the reality is that an efficient transportation system leads to minimization of cost and high satisfaction for the customer, which increase competitiveness and influence the relationships with customers. Therefore, it is a highly important task for every company to have efficient delivery services that will reduce costs and increase profits.
Logistics does not only include supply chain steps, but it also includes a lot of risks with it. Every company uses its way to perform logistic tasks, some of which use special software, and larger companies hire teams of employees responsible for logistics. In case a business underestimates the importance of the logistics and doesn't give necessary attention to the supply chain operations, it can increase difficulties that lead to cost, unhappy customers, and loss of profit.

Transporting of the purchased order can be different, including air traffic, sea transportation, or road transportation. The last one includes such essential factors as the choice and the number of vehicles, correct planning of the routes, distance, capacity of the car, the distance transport must go through in one day, and the time that the vehicle spends on the road as it must follow safety signs, cameras, or stop by to add fuel. Those indicators must be combined and considered when talking about logistics. By performing the supply chain of the businesses well and conducting the right logistics optimizations and countability of all sides and factors, the company can achieve better economic results and minimize costs.

Objectives and Methodology

2.1 Objectives

The primary goal of this thesis is to analyze the current supply chain situation by calculating the distances between the company and the clients. This study will revise the evaluation of the time of deliveries, current challenges, and the time plan of route combination. This thesis aims to create route combinations that minimize production loss from delayed deliveries, increase customer happiness, and business efficiency, streamline operations, and reduce costs by shortening the distances.

To be able to develop such route combinations that are close to the optimal, the distance matrix will be obtained with the use of open-source software. This matrix will be calculated through different methods such as the Nearest Neighbor algorithm, Savings algorithm, Vogel's approximation method, and Branch and Bound method in the Excel software TSPKOSA. By doing this, the idea is to optimize revenue while guaranteeing effective resource distribution throughout the network of supply chains. It will be followed by KPI calculation, which can indicate the company's performance and measure the "success" of the company by using the appropriate formulas, which are average delivery time of delivery and on-time delivery rate. This will help us make well-informed decisions and develop strategic plans to advance "Tulip" towards its operational objectives by enabling us to identify any positive or negative changes that could result from the deployment of new route combinations.

2.2 Methodology

This thesis will be divided into two parts: theoretical and practical. The time frame that will be considered in this thesis will be seasonal sales of 2023-2024, focusing on the highest demand on "Mother's Day" and "International Women's Day."

The company is in the town of Kochubeevskoe, in the south of Russia, and the customers are in two different regions Stavropol and Mineralniye Vody. Stavropol is located within fifty km of the main production and Mineralniye Vody is one hundred twenty-seven km away.

The theoretical part will include literature reviews and analysis of scientific articles that will include supply chains, logistics, traveling salesman problem, different methods of solving TSP, methods of solving TSP in software, and conduction of KPI calculations.

The practical part will include data collection from the available company, which is about current delivery plans, distances between retailers, production volume, delivery time frames, vehicle information, and an overview of deliveries in the last season. After this, data will be analysed and the distances will be transferred into the distance squared matrix. This matrix will be calculated using the open tool and obtain all information needed, such as definite distances of the retails. The initial coordinates were obtained using Mapy. cz. To perform optimization, the TSPKOSA software will be used with the data that was received in squared distance matrix. The TSPKOSA will calculate the closest to optimal route combinations using the following methods: Nearest Neighbour Algorithm, The Vogel's approximation method, Savings algorithm (parallel) and Branch and Bound method. The closest to an optimal solution will be chosen for this current delivery problem in "Tulip". Different methods fit different scales of the dataset; therefore, each method will be tested individually for each region. The route combination that will be obtained will be compared to the current delivery plan by calculating the KPIs. To implement a second vehicle to achieve more efficient delivery practices, the delivery situation and delay rates will be calculated. After that, the final economic analysis with the calculation of KPIs will be done.
This thesis combines theoretical ideas with practical analysis to be able to provide valuable information on how to optimize supply chain logistics for "Tulip"

3. Literature Review

3.1 Logistics

Logistics originated and was used even before the term “scientific” was coined. In the past, when there was a need for army weapons, many technical schools appeared to be able to build appropriate army equipment. “An army marches on its stomach” (Napoleon, 1812) – the phrase that took innovation meaning, due to better supply chain management of his military service compared to his opponents. Considerable stocks of beverages and army equipment were required to survive such difficult times; therefore, the logistic aspect of that matter was undoubted. Due to the separation of smaller poor armies and big trained armies, poor ones were also dangerous, as those had been robbing the inhabitants to get food; therefore, it was needed to improve logistics to such an extent that the army could get all things required to be able to perform on ongoing wars. It is necessary to mention that logistics play an essential role in political fights. (Brandimarte, Zotteri, 2007)

3.1.1 Definition of the logistics

It has not been so long since the usage of the word logistics belongs to everyday vocabulary. However, it is not so easy to strictly define it. Everyone nowadays takes it differently. Some of the meanings could include people distributing goods, others can belong to agricultural aspects, others can think that it is a plan to deliver goods to the customers, or someone can think of business when hearing the word logistic. But what is the real meaning of it?

“*Of course, we do not expect a single definition in the sense that we should always use the same words in the same sequence. The uniform definition should rather primarily clarify the relationships between the elements of logistics and its subsections, which for sure will give us the framework of logistics as discipline*” (Jereb, Kadlubek,2014)

There are also other definitions of the word “logistics”:

Kotler, Holt (1965) the author of the term in marketing as "marketing mix," defines logistics as arranging, carrying out, and managing the actual movement of raw materials and complied goods from the point of origin to the point of use to satisfy consumer demands and turn a profit.

Martin (2011), the author of the book "Logistics & Supply Chain Management" describes logistics as "*the process of strategically managing the procurement movement and storage of the materials, parts and finished inventory (and the related information flows) through the organization and its marketing channels*".

Logistics could be divided into three primary categories depending on logistical activities: cargo transportation, inventory management, and order processing. (Cui, Hertz, 2011)

- Inbound logistics

The word appeared by the connection of two different words: in (inne), "*within, inside,*" and bound (boun) "*ready to go*." Nowadays the word stays in the vocabulary and has the meaning of moving inward. Adding word logistics makes it possible to guess the signification of the word.

Miemczyk, Holweg (2004) explain "*inbound logistics*" transfer of products into business from an external source. Supplies are ordered, received, stored, transported, and managed throughout this process. The supply side of the supply-demand relationship is one of the main topics of inbound logistics.

- Outbound logistics

Outbound logistics is the opposite of inbound. An example of such can be an order that was received by a consumer or final point and was delivered from the distribution center.

The key finding concerning outbound logistics is that four factors—higher service levels, more frequent deviations, weaker trends, and acceptable reliability of multi-item measures - were linked to dyadic vulnerability in outbound logistics flows. The study also discovered that while larger businesses often offer greater service levels, their inbound logistics also saw more variances and weaker trends. Overall, the paper makes the case that businesses should focus on upstream supply chain operations to enhance their performance when interacting with consumers. It also provides a model of outbound dyadic vulnerability scenarios in supply chains to help businesses make informed decisions. (Jereb, Kadlubek, 2014)

- Distribution logistics

Distribution is closely connected to the word "*logistics*", it is not only the part that belong to it, but it also creates the term distribution logistics, which is very narrow to what most of the retailers use. To describe this term, it is important to mention what supply chain management and distribution networks are. SCM, shortened from supply chain management, is a regulation in a certain way. The focus is on buying and correspondence with suppliers. Supply chain management is closely connected to customer relationship management and enterprise resource planning, which leads SCM to be interdependent with all other departments such as accounting, marketing, etc. The places where the goods are stocked are part of the distribution network. Those locations usually go through inventories. However, it is very costly for many corporations, and it helps them stay on the market along with other competitors. Products go from the production places to the retailer, and this is the distribution network model. (Jereb, Kadlubek, 2014)

3.1.2 Transport

Nowadays, transportation theory refers to the past. L.N. Tolstoy was one of the first to perform the mathematical analysis of the transportation problem in one thousand twenty, though the problem was standardized even earlier by French mathematician Gaspard Monge in one thousand seventy-eight. His work "Methods of Finding the Minimal Kilometrage in Cargo-transportation in Space" was published in 1930 in the Transportation Planning Volume I collection issued by the National Commissariat of Transportation of the Soviet Union. During World War II, the Soviet mathematician and economist Leonid Kantorovich made significant strides in the discipline. The given problem is frequently called the Monge–Kantorovich transportation problem. The Hitchcock–Koopmans transportation issue is another name for the transportation problem expressed in linear programming. (Grazia, Speranza, 2018) Tolstoy discovered such a model to help distribute salt, cement, and other goods within the cities located within the railway network in the Soviet Union. The author examined the transportation problem, outlining many methods for solving it and the now-established notion that an ideal solution has a residual graph free of any negative-cost cycles. Tolstoy may have been the first to notice that the cycle requirement is required for optimality, as noted by (Schrijver 2002).

The growth of the issues in the field and the advancements in information and communication technologies were tracked throughout the history of contributions to logistics and transportation. Although the story of logistics and transportation is as old as humanity, it has recently experienced significant advancements. The airplane was discovered in 1903, and the railway at the start of the nineteenth century. The sea container was invented in 1956 and has had a significant influence on marine shipping. These days, the fundamental goal of supply chain management, including logistics, is to serve as a business function that can make items accessible when, where, and in the necessary amounts. Regarding business processes, transportation management may be considered a logistics component. However, people's transportation is just as important as that of products. (Wee, et al., 2023)

3.1.3. History of Transportation

Previously, it was difficult to imagine how things would turn and how transport would develop, like electric cars and planes can perform sixteen-hour flights without stops or spaceships. However, all that started with a simple wheel invention. On the side of Middle East, from current Iraq and Syria, there was a place named Mesopotamia. Most of the furniture was made from clay. Therefore, the potential wheel was also made from the clay and was supposed to be turning the desk to shape the form. With time making pots became something regular, however, transportation was still a big difficulty. Runners were connected to the sleds to be able to transfer stones. The question was not so often raised if there is any way to make hauling easier due to only muddy roads, which couldn't be used even if there would be better transport. Later, one of the most significant inventions became the chariot, which was pulled by the horses. It started to be used on different royal yards and for military services.

The exploitation of such carriers moved towards Europe and China with becoming the main sport on the Olympic Games in Greece. (Garrison, 2003)

In the fourteenth century four-wheeled coaches were constructed in Hungary. It was quite expensive to afford for an average person, therefore, it started to be popular to use such coaches as part of coach-for-hire services, it later would be considered as a model of current taxi cabs. In the seventeenth century it changed itself to be stagecoaches, where it was possible to make stops along the way to final destinations. After the wheel appeared, it changed the life of many countries, as an example the American inhabitants could move to other parts of the country, relocating or traveling with their families. (Garrison, 2003)

Early in the nineteenth century was a big success in manufacturing trains and marines in England, all previous inventions, such as steel, iron, telegraph, and others, played a crucial role in later developments. It would be essential to note the huge input of Brunel in steam-powered iron ships and Stephenson to railroad building. The latest railway and maritime appeared in the 1920s. After that, there were a lot of changes and enhancements in technologies, which brought a lot of changes to those findings. It also affected many rural and urban zones, where the last ones served as a stop for technical service. (Garrison, 2003)

3.1.4. History of tulips

Longer before the tulip had become one of the most recognized symbols of the Netherlands, it was not-so-famous flower, which took its beginning in central Asia and South of Russia, Caucasus mountains. Such the first breed of flowers, coming from the Caucasus mountains was called "Tulipa Eichler", It had long green leaves and was a perennial plant that grew from a bulb and produced flowers, typically red, bright color. These flowers spread towards Iran and Turkey due to a few explorers who would collect the seeds from such a bright and unusual flower. These were not domesticated flowers and were exclusively grown in wild nature; they spread rapidly with winds. (Pavord, 2019)

The tenth and eleventh centuries, the flower increased its popularity in Persia, where it became the main idea of many poems and writings. In the latest years of the fifteenth century, tulip bulbs were transferred to Europe, particularly to Germany, it was complicated to do, but it was possible to transfer those in clothes. (Lawrence, 1939)

In 1593, Carolus Clusius planted tulips in a Dutch botanical garden. Soon, these tulips became a big deal in the Netherlands. People were fascinated by the unique flowers. Clusius didn't want to sell them, but locals stole some bulbs. As years passed, tulips spread across the country. Tulips became super valuable due to a special feature: their colors changed over time because of a virus. This made them a hot commodity. Fancy tulips were rare and costly, making people eager to own them. By 1612, a book showcasing tulip varieties caught the attention of European royals. Tulip prices went up a lot. During a time when there was sickness and fewer workers in the Netherlands, many regular folks started investing in tulips, hoping to make money from their rising worth. (Kamenetsky, Hiroshi, 2013)

Tulip traders in the 1600s earned year-round profits. They started making future contracts for tulip bulbs. By 1635, tulip trading was formalized in Amsterdam and spread to cities like Rotterdam. Prices skyrocketed, a bulb worth fifteen florins could fetch one hundred seventy-five or even thousands of florins within years. By the year 1637, experts warned of a bubble. Panic selling ensued, leading to a market crash that affected the rich and the poor. (Garber, 1852)

Dealers staged fake auctions to manage the tulip crisis. Later, they proposed honoring pre-November contracts but allowed post-November cancellations with a percent penalty. The Dutch Supreme Court intervened, allowing sellers to sell to third parties. The government sent commissions to settle disputes, with most sellers agreeing to a reduction settlement. The economic impact was significant, with some suggesting England benefited from the Dutch turmoil. (Garber, 1852)

Tulips mostly grow in areas around the forty degrees north latitude, from places like Greece to countries like Turkey and beyond, reaching places like Uzbekistan and China. Today, countries like the Netherlands, Turkey, and the United States are big on tulip exports, while they're also popular in places like Japan and Canada. People used to bring tulips to Europe from places like Turkey and Central Asia. These flowers love cool places with some rain and dry times too, often seen in fields and gardens. (Pavord, 2019)

3.2 Operational research

The "*operational research*" is not something that could be described in one statement, it appears to be a very complex subject, without any straight definition.

Even if could try to simplify the meaning, it would not make any sense; therefore, it would be logical to use a few definitions to combine them and have more precise picture. (Marlow, 1993)

L. Saaty (2004) explains operational research as "*operational research is the art of giving bad answers to problems to which otherwise worse answers are given*" From one point of view this definition can be scientifically and philosophically satisfying, it still doesn't have the real deep idea and explanation of term, the dictionary meaning itself.

As per Bard and Jensen (2002) definition, the clearest explanation would be "*quantative common sense*", the meaning of quantitively bring the idea of numerical, logical, and pragmatic. This interpretation implements future decision-making processes and highlights the significance of adding mathematical models to practical solutions that would address real-world situations.

3.2.1. Phases of application of operational research

Phases of operational research might remind the phases of strategy of the project, which would include developing of certain plan and following it. However, operational research might differ in some parts, and usually it includes five stages:

initiation or problem definition, modelling, data collection, analysis, research, implementation, monitoring, and feedback. (Davidson, et al., 2007)

The operational research, closely to the project execution, include several stages or phases. Firstly, it would include definition of the problem and initiation of the research. Like initiating the project, the clear goals must be defined, and the problem must be understood and analyzed very well.

That must include and answer the questions such as:

- "*Does it bring any value*?"
-"*Expected outcomes and what are those*"

Next step must be modelling which would include the presentation of a mathematical model that would represent real-world scenarios and analyse the relationship between models. That step is especially important for researchers to understand the situation and complex systems better, therefore having more valuable results. That part could be supplemented by adding graphs to improve the understanding. (Fildes, et al., 2008)

Collecting the data plays a key role in operational research because the more data is available, the better results could be achieved. The data must be relevant and correspond to the initial condition. The study must be done within certain relevant fields and can be done through analysis of enormous datasets or include sampling, which sometimes can bring even more accurate results. It is essential to consider the limitations, such as implementing it is in mathematical model, which can sometimes idealize real-world situations and not consider very important human factors. The data must correspond to ethical norms and get necessary permissions and approvals, especially when working with sensitive data. (Hillier, et al., 2001)

As Morse, Kimball (2003) always analyzed problems by implementing any methods available, it could be optimization, simulation, or any other. The outcomes obtained must be structured, and evaluated. The decision must follow if the analyzed data brings any value or is logical, and in case it does, then the analysis must move to the next step research. This part includes resolution implementation and evaluation. After that, apply the chosen solution to the problem, acknowledging all potential risks and restrictions.

3.3 Travelling salesman problem.

The main idea of a travelling salesman is each of set of towns visited only once, with beginning and ending at the same point. The research for the shortest route for this traveling is one of the main issues. Many disciplines such as mathematics, computing science and operations research practice the travelling salesman problem or TSP. (Junger, et al., 1995)

The travelling salesman problem refers to the NP-hard problems according to Karp (1972), by the time when the NP-complexity theory appeared, the TSP was among the earliest to be proven NP-hard. (Junger, et al., 1995)

According to Knuth (1974) NP is a short form for the "non-deterministic polynomial - time hardness", it describes the problems that are essentially "*as difficult as, the toughest problems in NP*".

(Junger et al., 1995) Show the connection between the Hamiltonian Cycle and TSP. He mentions that TSP is NP-hard, taking into consideration that the Hamiltonian Cycle is proven to be NP-hard and being part of the list of NP-hard problems. The Hamiltonian Cycle problem can be explained as:

There is a graph $H\ (V, E)$. Does this graph have a route $T \subset E$, that could let visit each vertex only once?

One of the ways to solve TSP in this case can be described as: The graph $G\ (V, E)$ of length $w_{ij} > 0$ for each edge $(i, j) \in E$ and the value $M \in R$. Does the graph contain the route with length L, that $L \leq M$?

Assuming that solution has been chosen from the set of possibilities, this solution comprises a set of edges T, composing a routing. This set can be stored in polynomial space. To validate a solution, each vertex must be visited only once, and the route is devoid of any additional pathways. Then, the sum w_{ij} of all $(i, j) \in T$ and compare result to M. This can be done in polynomial time, so the solution variant belongs to NP. It is also demonstrated the solution variant achieves NP-completeness through reduction from Hamiltonian Cycle problem. If ethe example of Hamiltonian Cycle is true, then TSP is true. Suppose that there is tour g, with length no more than $M = 0$ with $T \subset E$ being set of all edges in the route. All lengths are not negative therefore $w_{ij} = 0$ for all edges $(i, j) \in T, T \subset E$. T is a set of edges of all cycle, then $w_{ij} = 0$ for all edges $(i, j) \in T$, all edges T formulate the route with length equals zero. NP solution is complete, and TSP is NP-complete. The total distance travelled along the Hamiltonian cycle and the requirement for its minimization can be written in the form:

$$C_{i_1 i_2} + C_{i_2 i_3} + \cdots + C_{i_{n-1} i_n} + C_{i_n i_1} \rightarrow min \qquad (1)$$

Where the formula (1) meaning the $C_{i_j} C_{i_{j+1}}$correspond to the distance between places, n means number of cities, i_n is a variable that represent the cities in Hamiltonian cycle.

In TSP the more cities to visit, the more complex the problem gets. Sometimes, not only mathematical methods could be implemented, but also, software solutions or solutions with coding methods. TSP plays a huge role in logistics and businesses, where the requirement to deliver goods from point A to point B and come back to point A, visiting each city only once.

According to Gent (1996), the TSP is a problem that is structured around the integer values. If donate, that $x_{ij} = 1$, when the salesman transition from city i to city j. If, $X_{ij} = 0$, it signifies the absence of a direct route between them.

Introducing the city $n+1$, positioned at the exact location, where the merchant commences the trip. From now on, from the starting city, only departures are allowed, while in city $n+1$, only arrival or entrance are permitted.

The supplementary integer parameter corresponds to the quantity of pathways leading to the city:

$$U_i = 1, U_{n+1} = n \quad (2)$$

The formula (2) represents n to be several cities and the parameter U_i shows the number of routes leading to circumvent cyclic, the salesman must depart from the initial city and return to $n+1$. Establishing the supplementary constraints that interrelate variables X_{ij} and U_i $i = \{1..n\}$, this array denotes the collective count of cities, which the salesman must go through. The matrix named C_{ij} gather data about the duration between travelling through cities, where $1 \le i, j \ge n$. The problem is symmetrical, if $C_{ij} = C_{ij}$ for all i and j. The travel expense or edge weight within the graph connecting two cities remains invariant regardless of the travel direction.

The mathematical description of TSP by Dantzig, Fulkerson, Johnson (1954)

$$min \sum_{i=1, j\neq i}^{n} \sum_{j=1}^{n} c_{ji} x_{ij} \quad (3)$$

$$s.t. \sum_{i=1, i \neq j}^{n} x_{ij} = 1, \qquad j = 1, \ldots, n; \qquad (4)$$

$$\sum_{i \in Q, j \neq i,} \sum_{j \in Q} x_{ij} \leq |Q| - 1, \forall Q \subseteq \{1, \ldots, n\}, |Q| \geq \qquad (5)$$

The formula (3) represents the minimization of the cost or total distance as objective function, where the c_{ij} respond to distance or cost, i, j are the cities and x_{ij} is a binary decision variable that equals to one if the tour covers the edge from city i to j; otherwise it is zero. Formula (4) represents the constraint that is that each city is visited only once. The total of all edges entering the city j must equal one, and the salesman must leave the city only once. Formula (5) is the limit that regulates that each city is visited only once. Q is a subset that must be min of two cities and equal to smaller than or equal $Q - 1$.

Dantzig (1954) states that those implementations have similarities with formulation proposed by Miller, Tucker and Zemlin, however the last one, which is named as sub tour elimination limitation, prevents smaller tours from forming within the main tour. This formulates the solution as one extensive tour. But dealing with those limitations, might influence in appearing too.

Miller, Tucker and Zemlin (1960) formulated the TSP and introduced it by using the additional variable, $u_i \in \mathbb{Z}$, that shows the sequence in which the towns are attended. With the meaning of u_i the location of the city i in the travel $u_i < u_j$, where i is before j.

$$\min \sum_{i=1}^{n} \sum_{j \neq i, j=1}^{n} c_{ij} x_{ij} \quad (6)$$

$$\sum_{i=1, j \neq i}^{n} x_{ij} = 1, j = 1, \dots, n; \quad (7)$$

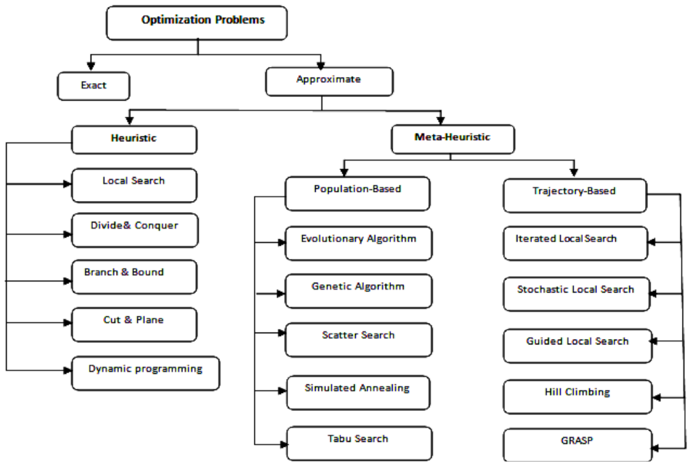
$$u_j - u_j + (n-1)X_{ji} \leq n-2; \;\; 2 \leq i \neq j \leq n; \quad (8)$$

$$1 \leq u_j \;\leq n-1, \qquad 2 \leq i \leq n. \quad (9)$$

Miller, Tucker and Zemlin (1960) in formula (6) show the objective function that tends to minimize the cost and distance, alike to formula (3) that has the same variables. The formula (7) corresponds to constraints. It proves that the limits here ensure that each city has a single connection to another city, another limit that it has only one departure to another city, and two limits make sure that there exists only one possible tour covering all cities. These conditions are vital to validate the solution as a legitimate tour encompassing all cities. Formula (8) represents variables that control each city that is visited only once. Formula (9) is named as MTZ constraints formula, where the u_j is a continuous variable that shows the city j in a tour, inequality $u_j - u_j + (n-1)X_{ji} \leq n-2$ guarantees that all edges from the city j to i is maximum $n-2,$ to prevent from subtours.

Different methods and algorithms have been created to solve these complex problems, split into categories. Hoffman, and O'Nelli (2001) have defined the travelling salesman problem as not difficult to interpretate, however very complex to resolve. The problem can be divided into smaller groups, which include much more subcategory algorithms. Mainly, methods are divided by exact algorithms, heuristic and metaheuristics and adapt to the initial condition of the problem. (Desale, et al., 2015)

Figure 1Taxonomy of optimization problems



Source: International journal of computer engineering in research trends, volume 2, (Desale, 2015)

Exact algorithms, according to (Junger, et al., 1995) create the whole search of combinations, it can lead to discovering the fast solution, but most of the time the search happens through all routes $n!$, where n is number of all towns. The TSP is NP-complete; therefore, the more points in the route circuit, the more complex the task is, which can make this kind of task useless because searching for an optimal solution will take millions of years.

1. Brute Force Algorithm

The brute force algorithm relates to the methods that exhaustively search for possible solutions. In the TSP method the difficulty of brute force algorithm implementation depends on the number of cities. If the number is too high, then the implementation of this algorithm can take up to years. The implementation of brute force algorithm can solve any problem of NP class, but minus this algorithm – is the time required for search for the best option, which grows exponentially. The Brute Force algorithm is usually implemented on easier tasks and small quantity of cities. (Junger, et al., 1995)

2. Dynamic programming method for the TSP

The method of a dynamic programming was offered by Richard Bellman (1950). Sometime later, the method became the most common in computer science and various optimization problems, including the usage of AI.

According to (Kool, et al.,2008) if $G = (V, E)$ graph with multiple vertices V and multiple edges E, $|V| = n$, $|E| = m$. The distance between vertices is set by matrix $C = \|C_{ij}\|$. The graph is assumed to be complete without loops and multiple edges. Components $C_{ij} = \infty, i = 1, n$. The starting vertex of the traveling salesman route will be considered vertex 1.

If $S \subseteq V$ meaning chosen to set of vertices. Minimum elementary chain takes beginning in the vertex 1, goes through each vertex of S and ends in the vertex $j \subseteq S$. Then using the optimality principle of Bellman, the equation is:

$$(S, j) = \min_{i \in s \setminus j} \{c_{ij} + f(sS/j, i)\} \tag{10}$$

With initial conditions that:

$$f(\emptyset, \emptyset) = 0. \tag{11}$$

Following the last step:

$$f *= \min_{i \in V/1} \{c_{ij} + f(V, i)\}, \tag{12}$$

Formulas (10), (11), (12) represent the length of the shortest elementary chain, that is represented by the function (S, j), that begin in vertex 1, and cycles around each vertex in the set S and stop at vertex j, where j is subset of S. The c_{ij} always represent the distance between the cities. Formula (11) shows the length of the chain with beginning and end on the same vertex. Formula (12) shows the size of the optimal tour, with $f*$ minimum length achieved. It is the smallest of all options, where the tour goes to each vertex preciously once before returning to vertex 1. The main advantage of such method is that it is universal because it is not sensitive to introduction of additional constraints. Later, this method was used to solve TSPs with choice, after that for TSPs with highlighted vertices, and even later for TSP with interacting pairs of items. The main disadvantage of this method is the high requirements to memorization (required approximately $\sqrt{n}\ 2^n$ and exponential complexity (requires $\mathrm{O}n^2 2^n$ manipulations)

(Kool, et al., 2022) shows how to solve dynamic programming algorithms for TSP:

Figure 2 Dynamic approach TSP

Algorithm 1: Dynamic Approach for TSP

```
Data:  s: starting point; N: a subset of input cities; dist():
       distance among the cities
Result: Cost : TSP result
Visited[N] = 0;
Cost = 0;
Procedure TSP(N, s)
    Visited[s] = 1;
    if |N| = 2 and k ≠ s then
        Cost(N, k) =dist(s, k);
        Return Cost;
    else
        for j ∈ N do
            for i ∈ N and visited[i] = 0 do
                if j ≠ i and j ≠ s then
                    Cost(N, j) = min ( TSP(N − {i}, j) + dist(j, i))
                    Visited[j] = 1;
```

Source: Dynamic approach, Kool (2022)

In the algorithm, N stands for the cities that will be visited, the journey will start from S and the interval is $dist$, cities are unified by the coded number $(1,2,3 \ldots)$. The starting travel expense is equal to zero. If there are only two cities in the subset, the recursive function provides the separation, but if more than two subsets, then the route would be as the length from the one city to the closest, but the length between the left cities is calculated recursively. In the final point, the algorithm comes back to the TSP solution. (Kool, et al., 2022)

3. Branch and bound method for the TSP

Balas, Toth (1983) mention the developers of "branch and bound" as well as the TSP algorithm. Those techniques are named enumerative and include branch and bound or implicit enumeration, the idea is to split feasible solution into smaller subsets, considering the objective function's value for each subgroup, and reject the others, that don't fit the criteria. The bounds are designated by substituting the problem with a simpler version, considering that the solution value of the new version is greater or equal to that of the original. The solution continues until the optimal solution, or there's no option to get better than the one obtained.

Balas, Toth (1983) applied the algorithm of the solution for TSP with branch and bound method:

1) Begin by initializing the problem and add TSP on the list of active subproblems. Set the upper bound to $U = \infty$, meaning there are no upper limit constraints.
2) If the roster is vacant: the initiary linked with U is optimal, if $U = \infty$, then no solution. In another case, follow to subproblem by aligning with rthe ule of selection, then remove TSP_i.
3) Resolve the relaxation R_i of TSP_i or determine the lower bound $v(R_i)$, denoted as L_i
If $L_1 \geq U$, go back to 2.
If $L_1 < U$,, if it outlines the route for TSP, mark it as best new solution, then if $U \leftarrow L_{ij}$, move to 6.
If $L_1 < U$ but the solution does not outline the tour, then go to 4.
4) Test the heuristic methods to find a solution. If obtain different more optimal solution, then reset U. Move to 5.
5)Eliminate the TSP_i and the arcs if that addition to a route would surpass the value above U. Move to 6.

6)Put in the application the branching rule to TSP_i. Move to 2

Heuristic methods are applied when the regular methods don't work, those aim to find the solution faster, even when it is not perfect or optimal. It is algorithms, that take less time but bring valuable solutions.
While meta-heuristic is "the guideline" that oversee the search process to efficiently explore solutions for near-optimal outcomes. They are not tied to specific issues and can find better solutions compared to basic heuristics. (Desale, et al.,2015)

4. Nearest Neighbour Method in TSP

The NN method, was a primary greedy algorithm that resolved the TSP. In this approach, the initial city is chosen arbitrarily, and subsequent cities are traversed based on their proximity to the starting town, ensuring no cycles are formed. This iterative process persists until all cities have been visited exactly once. (Smeaton, 1981)

Greedy algorithms – the idea of such is easy: by choosing the next city, the nearest city that hasn't been visited yet is chosen. However, often, the path seems short in the beginning, but the length can increase a lot toward an ending. In this approach, it doesn't matter what is the starting point of the algorithm. Usually, to improve the result it is better to test each city as a starting point, which can take a lot of time. It is common to this type of algorithm to be solved through software to reduce the time of calculations.

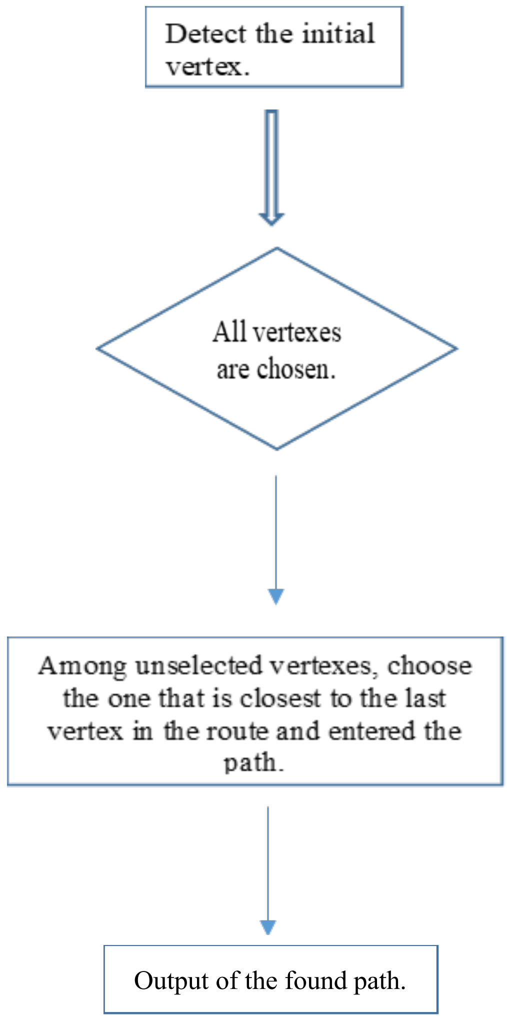
While the NN method is type of greedy algorithm, it does not guarantee an optimal solution for TSP, but it commonly gives a reasonable solution,
especially for big data sets and complex problems, where the solution is computationally infeasible (Walsh, Gent, 2002)

The block scheme of the Nearest Neighbor Algorithm is the initial step to define the initial vertex, meaning choosing the initial point is necessary. If all vertices are chosen, describing that all places visited only once as the initial condition of TSP.

Along the vertexes selected, the need is to choose the one that is the closest per the rule of the nearest neighbor algorithm, meaning that the vertex that is chosen to visit next depends on how close it is to the current point where. The basic idea is to choose a city that has not yet been visited and that is located near the location of the current time. (Desale, et al., 2015)

Once all places are visited, return to the starting point in finish the cycle.

Figure 3 Block-scheme of NN Algorithm

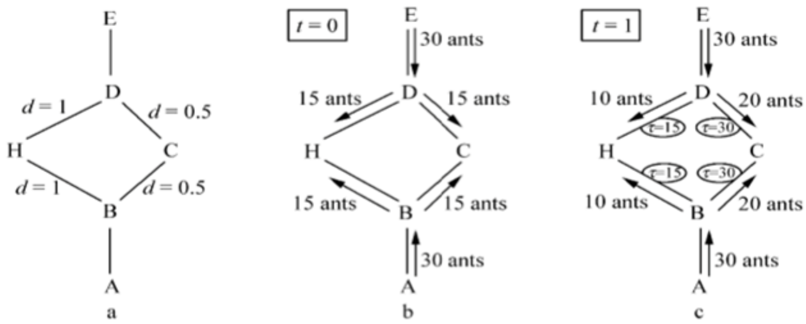


Source: own created based on research of Desale (2015)

5. Ant colony optimization method for TSP

ACO represents the behaviour patterns of actual ants, which can discover the fastest routes from the food to the nest without needing to use any visual senses, just relying on the pheromone. (Yang, et al., 2008)

Figure 4 Real ant colony search for the shortest path



Source: National foundation of China and Chinese Academy of Science, Yang (2008)

Picture (3) as aunts search for the shortest path from A to E. Initially, thirty ants are at point B and thirty are at point D, with no pheromone trails. They randomly choose paths, leading about fifteen ants each toward points H and C. As more ants travel, they lay down pheromone trails. New ants arriving at B or D detect these trails, influencing their path choices. Paths with stronger pheromone trails become more attractive, leading more ants to follow them. This process repeats until all ants converge on the shortest path. In n-city, TSP with distances d_{ij} they have arbitrarily allocated ants to n-cities. Artificial ants are significantly contrasted to real ants as they keep in mind the points (cities) they have attended and will not pick those again, additionally, they aware of the length between cities and favour the fastest. The chance that ant "k" chooses city "j" after city "I" could be expressed as:

$$P_{ij}^{k} = \begin{cases} \dfrac{\left[P_{ij}^{k}\right]^{\alpha}\left[n_{ij}\right]^{\beta}}{\sum_{s \in allowed_k}[\tau_{is}]^{\alpha}[\eta_{is}]^{\beta}} \\ 0 \end{cases} \tag{13}$$

The formula (13) consists from P_{ij}^k that the probability of ant "k" select "j" after attending city "i". τ_{is} is the amount of pheromone that connects the cities, n_{ij} is the level of attractiveness of moving from one town to another, $\alpha\beta$ is a regulation parameter that control the relative importance of the pheromone, j^k is the set of cities that ant hasn't been yet.

Ants are initially distributed haphazardly across cities, but they choose the next city according to the probability p_{ij}^k (per formula 13) Longer or shorter tours depend on the quantity of pheromone, its quantity is updated based on tour length and gradually evaporate over time.

$$\tau_{ij}(t+1) = p\tau_{ij}(t) + \Delta\tau_{ij} \quad (14)$$

$$\Delta\tau_{ij} = \sum_{k=1}^{l} \Delta\tau_{ij}^k \quad (15)$$

$$\Delta\tau_{ij}^k = \begin{cases} Q/L_k \\ 0 \end{cases} if\ ant\ K\ goes\ on\ edge\ (i,j), otherwise\ 0 \quad (16)$$

Where formula (14) represents $\tau_{ij}(t+1)$, that mean how much of pheromone is placed on the edge that links cities i and j by all ants. The formula (15) shows the $\Delta\tau_{ij}^k$ – symbolizes the addition made by the ant "k" on the edge of cities; the formula (16) consists from Q that means constant, signifying the quantity of pheromone deposit, L_k is the length of the route taken by the ant. Therefore, ant "k" deposits pheromone in proportion to Q divided by the tour length. (Yang, et al., 2008)

6. Savings algorithm (parallel) for TSP.

Referring to Tunnisaki, Sutarman (2023) how to solve the TSP as a saving algorithm. This method is straightforward, and though it cannot bring optimal solutions, it gives a pretty significant result that could be close to optimal. The method is broadly used when delivering goods to different final points, when the route choice is also significant. This method aims to bring a road combination that would minimize the total distance travelled. The distance reduction is processed by combining two routes into one as shown below:

Figure 5Basic representation of Savings algorithm

(a) (b)

*Source:*Scheduling of Vehicles from a Central Depot to a number of delivery points, Clarke and Wright, 1962

Clarke and Wright (1962) represent the saving method could be described in two ways: as a sequential and as parallel. While many routes can be generated at once in the parallel approach (a), only one route can be built at a time in the sequential approach. (b)

The basic algorithm that Clarke and Wright explain as "Saving method", can be described as:

1) Assembling necessary data, coordinates, all distance information, to create distance matrix.
2) The concept of the formula (17) "Value of saving" as (S_{ij}) consists of C_{oj}, C_{oi}, C_{ij}, which mean:
   C_{oj}-Distance from the company to the point i,
   ij- Distance from the point i to point j,
   S_{ij}- Value of distance savings from i to j

$$S_{ij} = C_{oi} + C_{oj} - C_{ij} \quad (17)$$

3) Choosing the maximum savings value $S_{ij}\ max$, from coordinating a "back-up road" to the chosen point, then decide which distance is the closest to the next track. Therefore, the combining customers of i and j, would be the representation of such

"savings." At the same time, if two routes can be merged into one, the "savings" of distance would be created.

$$S_{ij} = (C_{oi} + C_{io} - C_{jo})\text{-}((C_{oi} + C_{jo} - C_{ij}) = C_{io} + C_{oj} + C_{ij} \qquad (18)$$

The formula (18) shows that savings obtained by combining the routes from point I to the depot, and then from the depot to point j, the share reflects the savings. In the current thesis the saving algorithm will play a pivotal role in optimizing the routes for a transporting company and will be calculated in the practical part. (Pichpibul, Kawtummachai, 2012)

According to Ugur, Aydin (2008) due to a load of products needed to be supplied to customers, the idea of efficient distribution is big nowadays. The TSP plays a central role in many aspects of life, as the main idea of such, to find such route for delivering goods by attending each city on the way only once and return to start point would be cost-saving and optimal. But the number of cities or stops in between can be a very big number, which make problem very complex.

Nowadays, there are a lot of ways to calculate such, and many algorithms, methods, and software has been created. Some of them are very expensive and can be used only on special type of computers and in such fields as engineering or IT, but others can be available for everyone. This software located in Excel is TSPKOSA, which is available on every computer, so this can save a lot of time for smaller companies, who are struggling with route optimization and logistics.
In 2010, a collaborative effort between the Department of Systems Engineering and the Department of Statistics at the Czech University of Life Sciences in Prague led to the development of TSPKOSA. The authors of such are: Igor Krejci, Petr Kueera, Hana Vydvod. This program aimed to identify the most optimal routes for solving the Traveling Salesman Problem. TSPKOSA incorporated four distinct approaches:

- Nearest Neighbour Algorithm (sequential)
- Vogel's Approximation Method
- Savings Algorithm (parallel)

• Branch and Bound

To use the TSPKOSA, the distance matrix must be obtained with the help of other software or by calculation. The matrix must be squared and correspond to rules.

1. Vogel’s approximation method

The Vogel’s approximation method is time-consuming, and complex compared to other methods such as the northwest corner method or least cost method. However, it offers the closest to the optimal solution. In Vogel's method, the “penalties” method is implemented, they accrue when selecting the least favorable routes and which represent the absolute differences between the two smallest transportation costs per unit of cargo. These penalties are imposed when an unfavorable route is chosen. The core of the method involves identifying penalties across all rows and columns, selecting the highest penalty among them, and then filling empty cells with the minimum transportation cost, considering the row or column with the highest penalty. This process continues until cargo distribution among consumers is fully achieved. (Mathirajan, Meenkashi, 2004)

2. North-west corner method

The northwest corner method involves allocating shipments from one supplier Ai to meet the demands of a certain number of consumers Bj, where $j = 1...k, k \geq 1$, ensuring that neither the supplier's capabilities nor the consumer's needs are exceeded. Transportation costs per unit of product are disregarded in this method, anticipating further optimization. The transportation table filling starts from the top-left corner cell (1,1) and consists of repetitive steps. At each step, based on the supplier's inventory and consumer demands, only one cell is filled out, and consequently, one supplier or consumer is excluded from consideration, following the algorithm provided. The algorithm continues until cargo distribution among consumers $Bj, j = 1...n$ is completed. The resulting transportation plan obtained by the northwest corner method is always a pivotal one, as each step involves excluding a row or column, ensuring that the filled cells do not form a cycle. (Mhlanga, et al., 2014)

3.5 KPI

According to Asih and Sitorus (2020), KPI is a tool that every organization needs to follow up on performance of the company and goal achievements. It is excellent approach to measure the effectiveness of work, and avoid risks and errors, but sometimes KPIs can be measured wrong and lead to fake results, especially those mistakes are often associated when complex, wrong selected matrices measure KPIs. Therefore, choosing the correct approach referring to the initial goal and field is very important.

Parmenter (2015) notes three main advantages of using and implementing such measures: fair and clear goals, ability to coordinate and synchronize the staff actions with pivotal company success elements and influence on company execution through KPI's measurement. They are promoting values, empowerment, and teamwork within an organization.

This thesis will use the measurement of KPIs in the delivery field as the main topic refers to route optimization. Such companies that deliver logistics solutions or smaller businesses often need to know how their current state is and therefore it is common to implement such techniques.

According to Parmenter (2015), the formula for measuring delivery effectiveness would help recognize the average time taken to complete deliveries, and later, the result must be analyzed and compared to the "before optimization" situation.

$$Average\ delivery\ time = \frac{Total\ time\ taken\ for\ deliveries}{Number\ of\ deliveries} \tag{19}$$

Formula (19) represents the average time delivery, where the total time for delivery means the sum of time taken for each delivery divided by the quantity of deliveries.

Another approach that will help in measuring the expected delivery time and if the time is same as customer expected the order or if there are delays in the delivery, the analysis will be performed before and after the optimization methods. If the delivery time is reduced, or delays are not as common as they were, the customer will be more satisfied with the company.

$$On\ time\ delivery\ rate = \frac{Number\ of\ on - time\ delivery}{Total\ number\ of\ deliveries}\ X\ 100 \qquad (20)$$

The formula (20) represents how many deliveries were taken on time, divided by the quantity of total number of deliveries and multiplied by one hundred, the result must be in percentage. (Parmenter, 2015)

4. Practical part

4.1 Introduction to the problem

Effective logistics play a pivotal role in any business and at any field. The distribution of goods can affect customer satisfaction and operational productivity; therefore, it is essential for all businesses to connect with goods distribution somehow. The company that will be described in this diploma thesis, depends on delivery as variable of success. The delivery from the greenhouse directly to retailers must define the criteria of time efficiency, optimization, and customer satisfaction.

Local flower production in the south of Russia is in the rural area, where the agricultural sector plays a significant role. Harvesting or farming is the main source of income for many citizens there. The company's growth aim is around one and a half million of bulbs yearly, without considering defects or other inconveniences. Due to low demand for tulips in the countryside, the delivery goes to the nearest towns or regions, where the population is higher.

Typically, two cars would be quite good to perform the logistic tasks well, but as business grows, perfect delivery scenarios and on-time deliveries become challenging. Driven by a dedication to excellence and productivity, the company works to streamline its delivery routes so that colorful flowers arrive on time at locations throughout the rural area. The landscape is full of mountains, and the weather might be unpredictable sometimes leading to complications in the delivery; therefore, step into optimization of the current route would be critical to increase customer satisfaction and productivity.

According to the company CEO, logistics was not primary goal on their list, and they were mostly concerned about the increase in production and marketing rather than efficient delivery, which they accepted could be not the best tactics.

The company's task is to determine the most effective method of delivering all these flowers to the customers. Ensuring the flowers arrive promptly and in good condition is their goal destination.

Objective is to assist the organisation in increasing its business and delivering flowers more quickly.

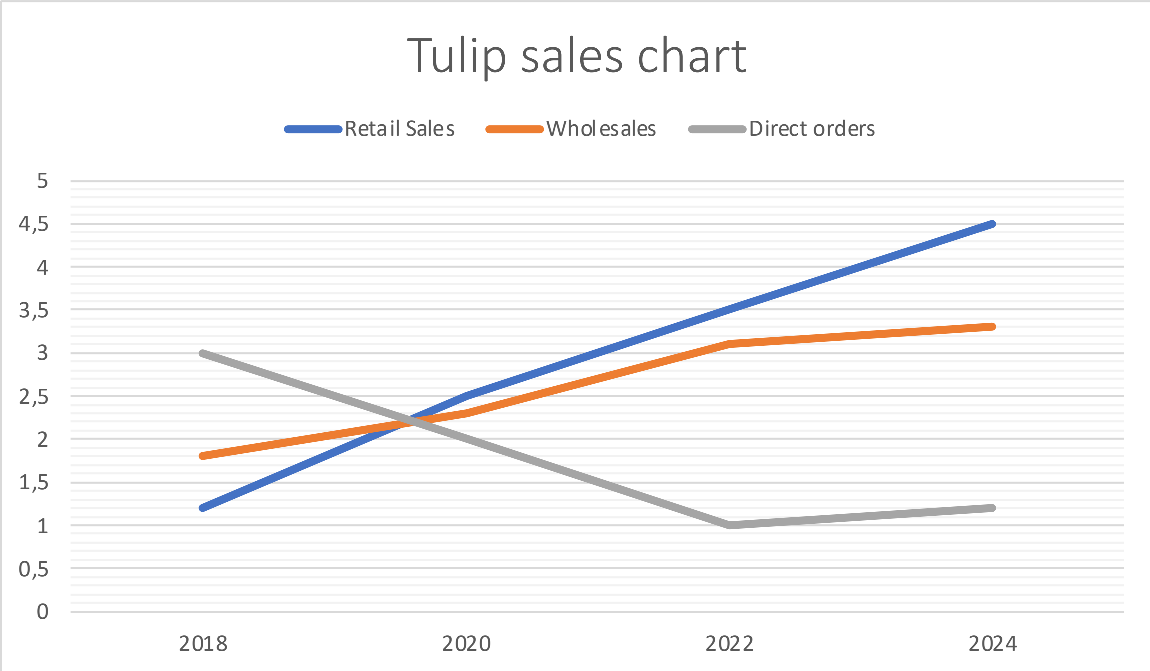
For several reasons, the TSPKOSA calculation was chosen over the performing calculations by hand. The calculations with the usage of software are advantageous method compared to the manual. It provides more accurate solutions, when calculating large-scale problems, and it is also less time-consuming. Because TSP is known as a complex problem, the TSPKOSA software provides solution with the ability to choose between heuristic and exact methods. It is easily accessible through Excel and advanced enough to perform the calculations of such big datasets as “Tulip” has provided.

It also allows to test the possible methods easily and compare the results to be able to choose the desired one. TSPKOSA software as mentioned before, specifically focused on calculations using Nearest Neighbour algorithm, Vogel’s approximation method, Savings algorithm and Branch and Bound. The software's methods are well known for providing practical and efficient solutions. While other methods can bring also valuable results in an optimization problem, those methods are not included in the software, which was main idea of this thesis. Additionally, the methods that was used in the software are exact optimization methods and simple heuristic methods, it gives a variety of opportunities to test them fast and make conclusions without spending too much time on manual calculations. The problem that “Tulip” has been struggling with is a lack of time-efficient deliveries and incorrect distribution of tasks, therefore the software solution would be a great asset for them, because it will save a lot of time and still allow choosing the desirable method, or simply the fast one compares them all. However, the Branch and Bound method is famous for the bringing the closest solution to optimal, the constraint of such is that when the dataset is too big, the method will not work.

4.2 Characteristics of the problem

The company Tulip is a small business, located in the south of Russia in the small town named Kochubeevskoe, it is surrounded by mountain landscape and a lot of rural areas. The company was created in 2017 and since then, it has been increasing its production yearly. The company operates retail sales, wholesales and direct orders.

Figure 6 Tulip sales chart

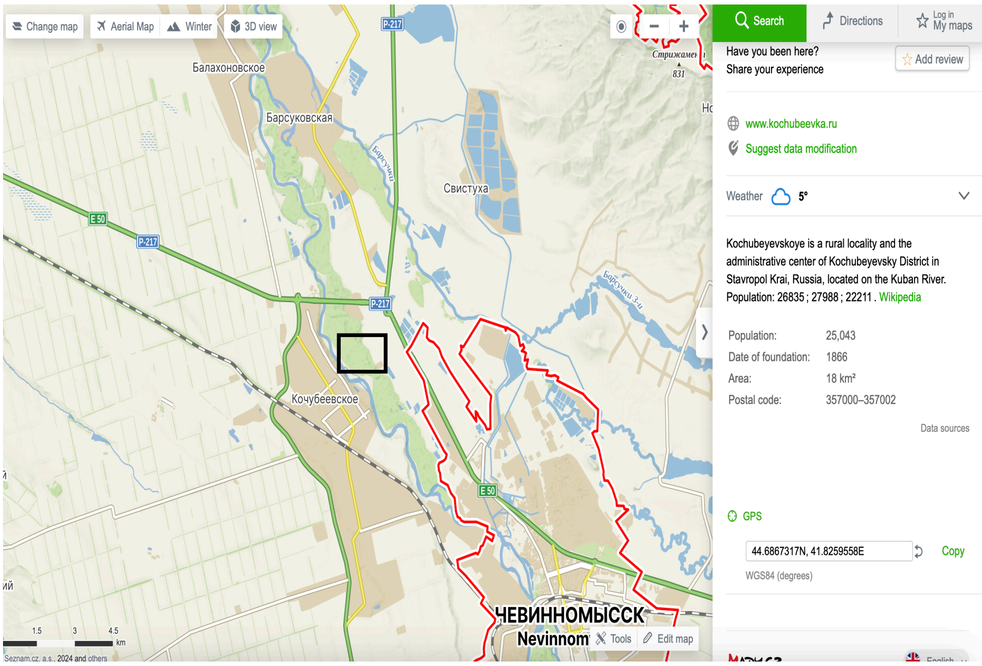


Source: own created, based on data provided by Tulip.

The current thesis will dive into the problem of retail sales, which requires the delivery and logistics involved. These sales represent orders from shops around the area and delivery to those directly. Wholesales represent much bigger orders and therefore usually client picks up orders himself. The process is that those wholesales are usually pre-order certain types of tulips up to 3 months before harvesting, and those orders are up to 50000 tulips. Direct sales typically consist of one or two bouquets, and those also do not participate in the delivery process, but the client directly picks it up from the production.

Figure (6) shows that from 2018, when the production only started, and the customer base was not so extensive, direct sales dominated. Mainly the company focused on clients who wanted to buy bouquets for events like birthdays, weddings and so on. Then wholesales, which was on second place and the amount of one sale like that was not so big, therefore usually it was customers who was buying in to sell later to direct orders not for distribution to retail. Finally, retail sales were low due to the small base of customers, which took years to gain trust and loyal customers. As time passed, the graph changed, and retail sales became the most significant part of production, followed by wholesales, which are already pre-sold for further distribution among retailers in different regions, and the last is direct sales, which is a very small part of the business. This graph not only represents the tulip sales chart but also shows how an increase in production changes the direction of the business itself.

Picture 1 Production area on the map



Source: own created, based on data provided by Tulip, mapy.cz

Picture (1) shows the production area on the map, marked as zone X, with coordinates 44.6861114N, 41.8238814E, the area itself is in surroundings of Kochubeevskoe, the production located in rural areas and located between wheat fields. The only road connecting it to the main highway is “P-217”. The path runs from the town of Yarag-Kazmalyar, which marks the border with the Republic of Azerbaijan, to the village of Pavlovskaya in the Krasnodar Krai.

This road goes through Stavropol, which will be analyzed later as a delivery center for many retail shops. The highway connects to the "M-4" and is 1118 km long. The road segment connecting Pavlovskaya and Makhachkala is a segment of European route "E50". Highway "E50" will be used for delivery of flowers to some of the retailers, as it is the main road how to get to Minerlaniye Vody.

Picture 2 Greenhouse of the company TULIP

Source: Own taken photos, real-time images.

Picture (2) shows the photo that was taken at the greenhouses of "Tulip". Two vehicles were used for logistics purposes. According to the company CEO, usually those vehicles are not used simultaneously, because of the cost savings and idea to go around all towns at once. Currently, they followed the plan that one region would be attended at a day, for example, two times per week they go to Stavropol by using the same vehicle, and two times per week they would go to Mineralniye Vody, therefore they need to travel four times per week to deliver the ordered flowers.

Picture 3 Vehicles used by the company Tulip

Source: Google Images, online, based on the information provided by "Tulip"

The Picture (3) represents two vehicles that the company operates with. The first one is Peugeot Partner, which has a fridge on the back of the car that make the vehicle very adaptable for delivery of flowers on hot summer days. However, the capacity of the vehicle would be an average five thousand tulips without boxes. The other car is a Fiat Ducato, which is used closely to some holidays when the delivery amounts increase. The capacity of the Fiat Ducato would be an average of eight thousand. In Fiat Ducato, the transportation can be only in boxes. Otherwise, the flowers would be broken. The process of packaging is visible on the picture (2), as the size of the boxes.

Picture 4 Packaging process

Source: Tulip Co, Real time image.

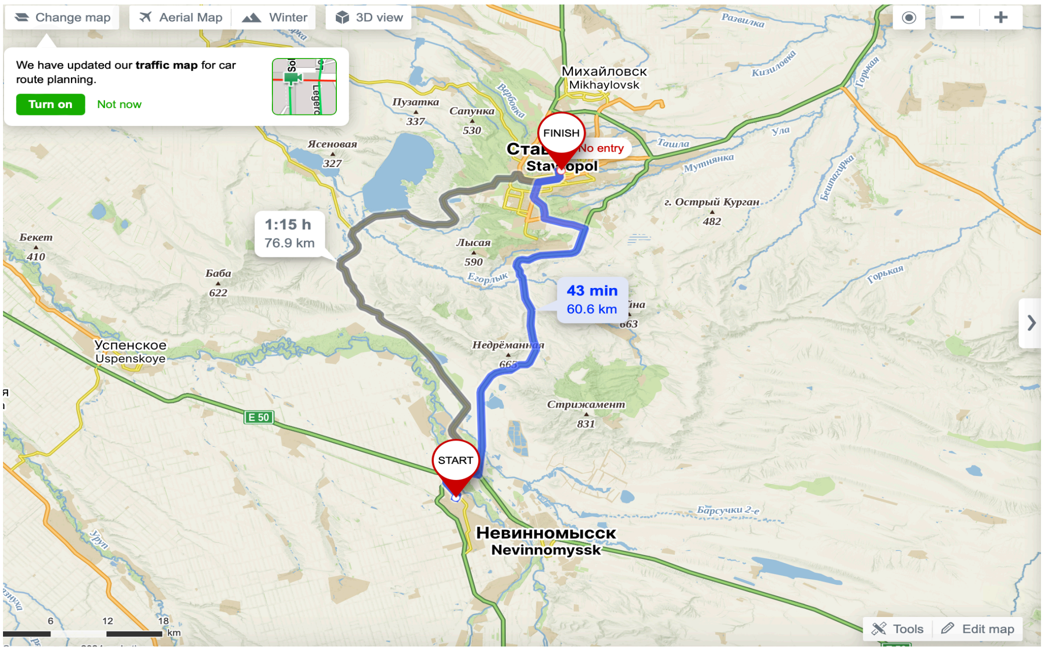
Picture (4) describes the packaging process in “Tulip” greenhouses.

The driver uses only one car which depends on the number of flowers to be delivered. As the demand is usually higher closer to the holidays, this lead to increase in sales, and therefore the bigger car is usually implemented. This thesis will consider the implementation of the second car.

The distribution area is not big, it is located within the same region, however below the picture (3) exactly describes how much km it is to travel to the final destinations.

Below on picture (5) is a map showing the travelling from Kochubeevskoe to Stavropol. It is possible by using two different ways, it is the main P-217 highway, which will take 43 min and it is 60.6 km, and the other way traveling on another country road outside of the highway, which will require 1h15min, 76.9 km.

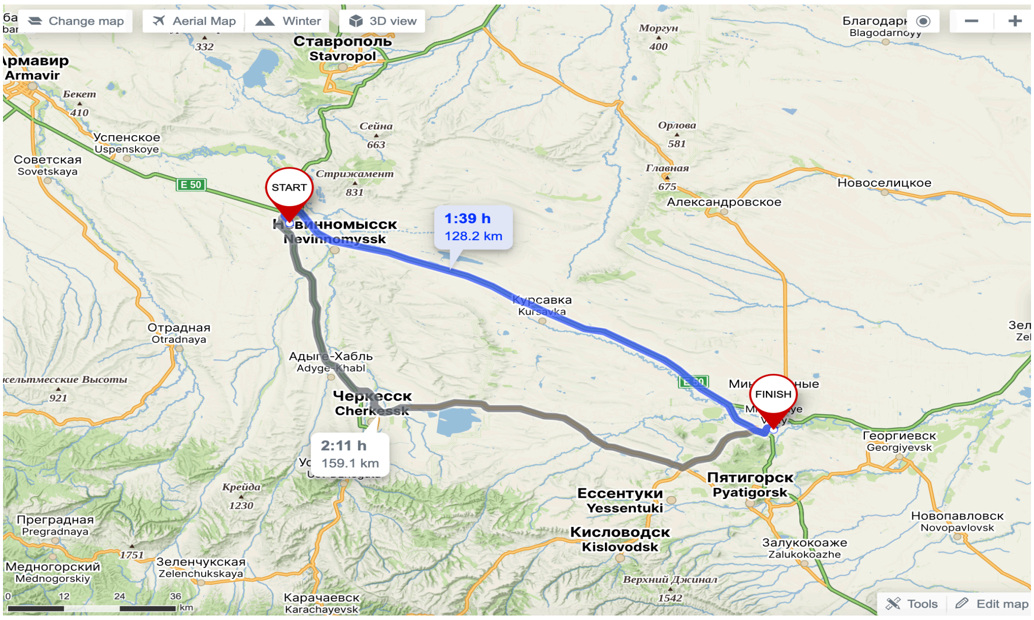
Picture 5 Representation of the route to Stavropol from the production point



Source: own created, on mapy.cz

The picture (6) describes the route from Kochubeevskoe to other retail locations, in the Mineralniye Vody. There are two ways available but following the main highway E-50 time will take 1:39h and 128.2 km. Traveling to Stavropol takes less time and less km from the production point.

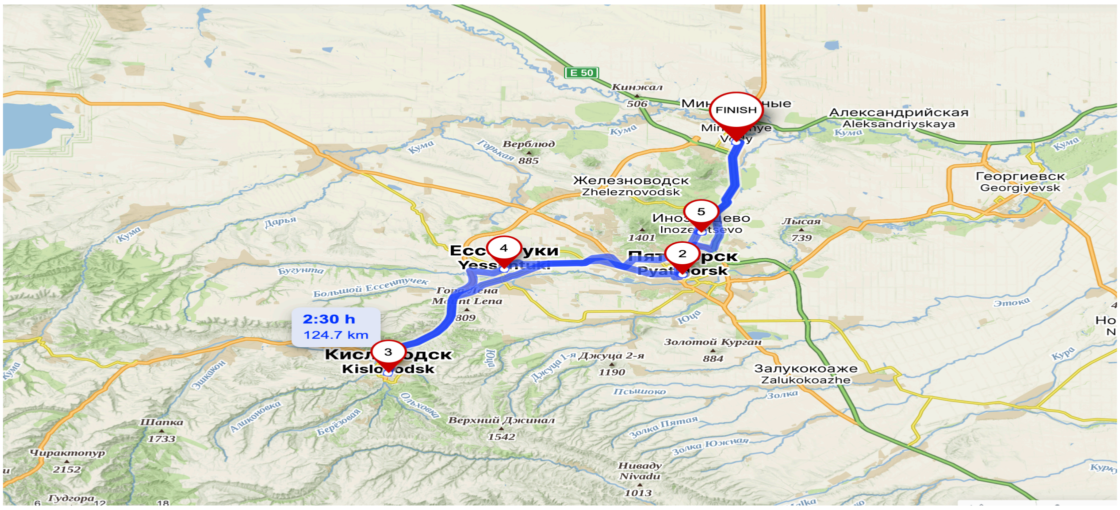
Picture 6 Representation of the route to Mineralniye Vody from a production point



Source: own created, on mapy.cz

According to the distribution plan of the company, when Mineralniye Vody is visited, the driver continues to follow the route by visiting Pyatigorsk, Kislovodsk, Yessentuki, Inozemtsevo+Lermontovo, Zheleznovodsk, and return to Mineralniye Vody. This route currently takes 142.4 km and takes an average of 2:49h.

Picture 7 Representation of the route to Mineralniye Vody + surrounding towns



Source: own created, on mapy.cz

Picture (7) shows the towns visited by the driver on the map. As it is shown in the picture (7), traveling to Mineralniye Vody and its surroundings can become a big challenge. If the quantity of shops increases, it can lead to a collapse without optimization and bring more not satisfied customers, complaints, an increase in costs, and reduce the fresh flowers deliveries in summer days. Because regular driving time will increase, as usually on average time to stop in one shop would be up to 15 min, overall taking up to 4:10h.

Table 1 Addresses of the retails in Mineralniye Vody, Tulip cooperates with

Customers	Addresses
A0 Mineralniye Vody	
A1 Lena Levokumka	Mostovaya 53/4, Levokumka
A2 Masha Anzhevskogo	Anzhievskogo 4, MV
A3 Galina Min. Vody main market	Internacionalnaya 37, MV
A4 Jana Min.Vody	22 Party Congress, 133B, MV
A5 Lena Min.Vody	50 years of October Street, 46A, MV
A6 Marina	Proletarskaya 23, MV
A7 Olya 7 roses	50 years of October street, 46A/1, MV

Source: own created, based on the data Tulip provided.

The table (1) shows data that was officially provided by the company "Tulip" and represent retail locations within the network they work and cooperate. The company sorts its client data based on the client's name, not according to the shop name. This dataset completes information about the locations within Mineralniye Vody and customer names. The table consists of seven rows, where each represents certain client information. The identifier "A" represents customers that belong to the Mineralniye Vody group. The address column provides the actual address linked to every place. According to the table there are in total seven customers that belong to the group Mineralniye Vody.

Table 2 Addresses of the retailers in Zheleznovodsk that Tulip delivers to.

Customers	Addresses
B0 Zheleznovodsk	
B1Natalia	Lenina, 104A
B2 Marina	Lenina 165

Source: own created, based on the data provided by Tulip.

Table (2) above represents the dataset that was provided by "Tulip" in another town located within the region of Mineralniye Vody, named Zheleznovodsk. The town is small itself, therefore the flowers are not in high demand, and "Tulip" has only two customers there. The identifier B represents Zheleznovodsk and customers within this town.

Table 3 Addresses of the retails in Lernontovo+Inozemtsevo that Tulip delivers to

Customers	Addresses
C0Lermontovo+Inozemtsevo	
C1 Ksusha	Lermontova 29
C2 Main market Inozemtsevo	Gagarina 207/1, main building

Source: own created, based on the data provided by Tulip.

Table (3) defines the dataset that was provided by "Tulip", however in another town located within the region of Mineralniye Vody, named Lermontovo. Due to geographical specifics, the Lermontovo town officially united with village Inozemtsevo, therefore, in this thesis, it will be counted as one town instead of two. Like Zheleznovodsk, there are only two customers. The identifier C represents Lermontovo + Inozemtsevo and customers within this town.

Table (4) below above represents Pyatigorsk and its customers; the city has identifier D and has ten customers, who work with "Tulip". The identifier is D for Pyatigorsk.

Table 4 Addresses of the retails in Pyatigorsk, that Tulip delivers too

D0 Pyatigorsk	
D1Masha P.	Mira 178
D2 Arevik	Mira 248
D3 Violetta	Dzerzhinsky 35
D4 Ksyusha 1	Infantry Devision 2A, p2
D5 Inna	Infantry Devision 2A, p1
D6 Gayana	Yutskaya 29
D7 Nelli	Ave. 40 years of October 30
D8 Kostya Krocus	Essentukskaya 29D
D9 Tatiana	Komarova 35
D10 Zarema	Kozlova 29
D11 Kamelia	Kalinina 299 A

Source: own created, based on the data provided by Tulip.

Table 5 Addresses of the retails in Kislovodski that Tulip delivers to

F0 Kislovodsk	
F1 Amina	Pobedy 141
F2 Kristina	Krasivaya 36B
F3 Olga	Pobeda Avenue 12B
F4 Asya	Heroev Medikov 10
F5 Nastya	Gorky 9G
F6 Natalia	Dzerzhinskiy Ave. 25
F7 Katya	Territorialnaya 1
F8 Angelina	Dzerzhinsky 45
F9 Nadezhda	Dzerzhinsky 45/1
F10 Rita	Pobeda ave. 124B

Source: own created, based on the data provided by Tulip.

Kislovodsk will be represented by ten customers and will be identified as F, shown in table (5), with the exact addresses of the retailers located there.

It is clear from comparing towns within the Mineralniye Vody area that the number of clients they service varies. The towns are listed according to decreasing client volume as follows: With eleven clients, Pyatigorsk is in first place, followed by Kislovodsk, Mineralniye Vody, Essentuki, Lermontovo + Inozemtsevo, and Zheleznovodsk.
The representation of such would be defined as: $D - F - A - E - C - B$.

Additionally, another region will be examined, as Tulip delivers flowers there as well. Stavropol is not only the name of the region but also the main city of that region. The customer base in that city has potential as the city constantly grows and industrializes. The “Tulip” plan is to expand the customer network within this city and the closest villages in rural areas. Table (6) below contains the addresses of clients with whom the Tulip is cooperating within Stavropol.

Table 6 Addresses of the retailers in Stavropol that Tulip delivers to.

S0 Stavropol city clients base	Addresses
S1 Ilona FF	Mira 274
S2 Anna Tsum	Dzerzhinsky, 106
S3 Sasha + Misha Pushkinsky market	Pushkina 8A
S4 Alena oK	Dovatertsev 61
S5 Luda 50 Let VLKSM	50 years of Komsomol Ave., 32A
S6 Ira Tuchachevskiy market	50 let VLKSM, 16l
S7 Natalia Tatarka	Soviet Army -2
S8 Sergey Dari Cvety	Lenina 392
S9 Katya FC	Lenina 318/2
S10 Raya Yunost	Tukhachevsky, 23/1
S11 Angelica Cvetochniye Ludi	Tukhachevsky, 27/1
S12 Alena Floer	Tukhachevsky, 24/1
S13 Dmitri Zavodskaya	Zavodskaya 11
S14 Anatoliy Michailovsk	Shosseinaya 22
S15 Armen Serova	Serova 203
S16 Olga Kosmos	45th Parallel ave., 3B
S17 Natalia Salut	50 years of Komsomol Ave., 5

S18 Regina	8th March, 69
S19 Vika	Lenina 228
S20 Inna Rosa Lux	Rosa Lux. 38
S21 Nastya Rumba	Tukhachevskiy 25/2
S22 Tatiana BG	Dovatertsev 88V
S23 Alexander Pro buqet	Tukhachevskiy 28/1
S24 Karina Partizanskaya	Partizanskaya 3
S25 Tatiana T	Tukhachevskiy 26/5
S26 Lera K	Komsomolskaya 65
S27 Olya Makov cvet	Goleneva 70
S28 Olya Niz Serova	Lenina 108
S29 Yulia sav	Savchenko 38
S30 Katya Tashla	Kulakova 51
S31 Nadezhda	Rogozhnikova 27
S32 Denis Natalia	Shosseynaya 20

Source: own created, based on the data provided by Tulip.

Table (6) depicts customers in Stavropol identified as "S," with a total of thirty-one customers currently collaborating with “Tulip”. When comparing the two regions, the number of customers in Mineralniye Vody exceeds that in Stavropol by merely four customers, rendering the customer bases relatively similar. However, deliveries in Mineralniye Vody often take longer due to the necessity of traveling between towns along highways. The proposed optimization plan entails utilizing Excel software to create a specific matrix. The coordinates of each city and sales point are necessary to generate this matrix.

4.3 Current delivery plan

The current flower delivery services offered by “Tulip” between the areas of Stavropol and Mineralniye Vody are described in this section.

The company “Tulip” operates with a single delivery van. The car makes two weekly excursions. Similarly, as the vehicle travels to Mineralniye Vody it travels to Stavropol twice a week, using a prearranged route to stores and finish flower deliveries. The path is designed to pass by every store in the vicinity.

This current delivery strategy provides the operational foundation for “Tulip” flower delivery services. With just one car inside careful planning and execution guarantee that every client in Mineralniye Vody and Stavropol receives service.

The following sections will discover the possible improvements that might be made to the delivery system, such as integrating new approaches and technology to maximize effectiveness and satisfy customers.

As previously mentioned, the logistics were not a priority thing to improve for “Tulip” in the past. However, it resulted in delays in the delivery and some customer complaints. The table below will contain Mineralniye Vody's current route that the company implements with its distances and time-consuming. The shops were numbered in tables (1)-(5) and the next tables will use only identifications, not full names of the shops and customers.

The analysis of the routes will be performed by hand with calculations with the help of mapy.cz.

The current route scheme for Mineralniye Vody was officially shared by the company “Tulip” and represented below, considering the starting and final point would be Kochubeevskoe (0).

Numerical representation:

[0]-[2]-[1]-[3]-[4]-[6]-[5]-[7]-[8]-[9]-[10]-[11]-[13]-[15]-[14]-[12]-[19]-[17]-[16]-[18]-[20]-[21]-[23]-[22]-[25]-[24]-[27]-[26]-[28]-[29]-[30]-[31]-[36]-[33]-[34]-[35]-[0]

Alphanumerical representation according to identifier:

[0]-[A2]-[A1]-[A3]-[A4]-[A6]-[A5]-[A7]-[B1]-[B2]-[C1]-[C2]-[D2]-[D4]-[D3]-[D3]-[D1]-[D7]-[D6]-[D5]-[D8]-[D9]-[D10]-[E2]-[E1]-[E4]-[E3]-[E6]-[E5]-[F1]-[F2]-[F3]-[F4]-[F10]-[F6]-[F7]-[F8]-[0]

Table 7 Current route delivery order Tulip implements. Min.Vody.

Delivery Identifier	Distance (m)	Time (min)
A2	129000	94
A1	6600	11
A3	5500	11
A4	1600	4
A6	1800	4
A5	1500	3
A7	200	1
B1	19700	18
B2	260	1
C1	20500	21
C2	16100	22
D2	10700	16
D4	4600	8
D3	3500	7
D1	2800	6
D7	3100	6
D6	4500	8
D5	8100	17
D8	7200	13
D9	2200	5
D10	4400	11
E2	17600	23
E1	600	1
E4	1300	3
E3	5500	10
E6	4500	9
E5	6700	11
F1	21200	23
F2	1800	5
F3	3500	4
F4	1600	3
F10	3900	10
F6	5000	9
F7	270	1
F8	450	2
Kochubeevskoe	151000	131

Total	**342880**	**532**

Source: own created based on data from Tulip and mapy.cz

According to the current route that the company implements for deliveries, the total distance is 342880 meters or (342.880 km), with the time spent on delivery being 532 minutes or (8.8h).

The current route scheme for Stavropol was officially shared by the company "Tulip" is represented below:

Numerical representation:

[0]-[7]-[14]-[1]-[2]-[19]-[3]-[4]-[5]-[6]-[7]-[8]-[9]-[11]-[10]-[12]-[15]-[13]-[16]-[17]-[18]-[20]-[21]-[22]-[24]-[23]-[25]-[32]-[20]-[31]-[28]-[26]-[27]-[0]

Alphanumerical representation:
[0]-[S7]-[S14]-[S1]-[S2]-[S19]-[S3]-[S4]-[S5]-[S6]-[S8]-[S9]-[S11]-[S10]-[S12]-[S15]-[S13]-[S16]-[S17]-[S18]-[S20]-[S21]-[S22]-[S24]-[S23]-[S25]-[S32]-[S30]-[S31]-[S29]-[S28]-[S26]-[S27]-[0].

Table 8 Current route delivery order Tulip implements. Stavropol.

Delivery identifier	Distance (m)	Time (min)
Kochubeevskoe (0)		
S7	4800	44
S14	20900	25
S1	13300	19
S2	2200	5
S19	1200	3
S3	1500	3
S4	6000	11
S5	650	3
S6	700	2
S8	3300	6
S9	1300	4

S11	8400	15
S10	4200	9
S12	2200	6
S15	7500	13
S13	4800	8
S16	13600	22
S17	2900	6
S18	3600	8
S20	3200	7
S21	9500	18
S22	6300	11
S24	8100	13
S23	5300	10
S25	2000	5
S32	25400	31
S30	23300	30
S31	14200	23
S29	400	2
S28	10500	20
S26	900	2
S27	290	1
(0)	54700	58
Total	**267140**	**443**

Source: own created, based on data provided by Tulip and mapy.cz

Per the current delivery plan choice, presented in Table (8) the company uses a total distance equal to 267140 meters or (267.140 km), time spent is 443 minutes or (7.3h). That route combination was calculated considering [0] the starting point Kochubeevskoe.

Setting up a benchmark performance indicator is essential before you can take any optimization steps. Consequently, the calculations are the average delivery rate for each current route plan to quantify the Key Performance Indicator (KPI).

$$Average\ delivery\ time = \frac{532 + 443}{4\ (per\ week)} = 243{,}75\ min$$

The Average delivery time equals 243.75 min, which represents average time four times per week. The number is high and corresponds to the current delivery plan. The KPIs show that the problem with delivery exists due to a very long time of deliveries, and that the optimization process of the current deliveries is required to be able in the achieve their goal of expanding customer network, reducing costs and grow the volume of sales and production.

4.4 Optimization with TSPKOSA software

The current problem of the company "Tulip" is that it is taking too long to delivery flowers. The company claimed that they prefer to use one car due to high production volume. In other words, they are not able to deliver all flowers at once, so they must do two trips to each region weekly, two to Mineralniye Vody, two to Stavropol. The company didn't prioritize logistics and according to their record it was convenient using only one car. However, the optimization solution that will be calculated in this thesis will not only be helpful for shorten the route and cutting the costs but will show that implementing second car will not decrease the profit, opposite way, following the new routes will make it more efficient and reduce costs.

To be able to perform in the software, the distances must be placed in distance matrix order. To obtain the distance matrix, the key data must be available. This information will include data about final nodes and addresses, in this thesis, it would be represented as customers and locations of retails. While all this data is available, it is possible to create a distance matrix by using the Open-Source Routing Machine. Using this tool, it is possible extract the distances between places based on the GPS coordinates. That distance matrix is required to experiment with different approaches for the solution of TSP and bring the closest to optimal one by using the TSPKOSA.

The software allows calculations to be performed using four methods. Depending on the size of the matrix, some methods can be complicated to use.
The methods that TSP KOSA operates are the nearest neighbor algorithm, Vogel's approximation method, Savings algorithm (parallel), Branch, and Bound. However, most of the methods weren't as effective as the Savings algorithm solution due to the size of the issue.

The Branch and Bound method, known for its efficient solution, has been a challenge in this optimization problem. The main reason was that to apply the method, the problem must have been divided into a tiny component. Unfortunately, this method could not produce precise answers, making it impracticable. Therefore, this method would be suitable for problems that don't cover such a big area as "Tulip" does.

After the multiple testing of each method, the results tend to show that the Savings algorithm is the most effective approach, which brings to the solution which is closest to optimal.

The routes have been tested in different ways, a single way to Mineralniye Vody and Stavropol, and the combined road, meaning that the driver must visit Stavropol and Mineralniye Vody on the same day. However, it will not be possible due to several flowers that have been ordered, because, to finish the delivery, the company must either implement another car, which would lead to separate optimization of regions, or travel the next day, which would mean the same. Therefore, each area was evaluated independently based on the best explanation.

Table 9 TSPKOSA testing results

Method chosen	Result in Min.Vody region (m)	Result in Stavropol region (m)
Nearest Neighbor method	178757	78825
Vogel's approximation	195863	80842
Savings algorithm	**175673**	**75550**

Source: own created, based on data provided by Tulip and TSP KOSA results.

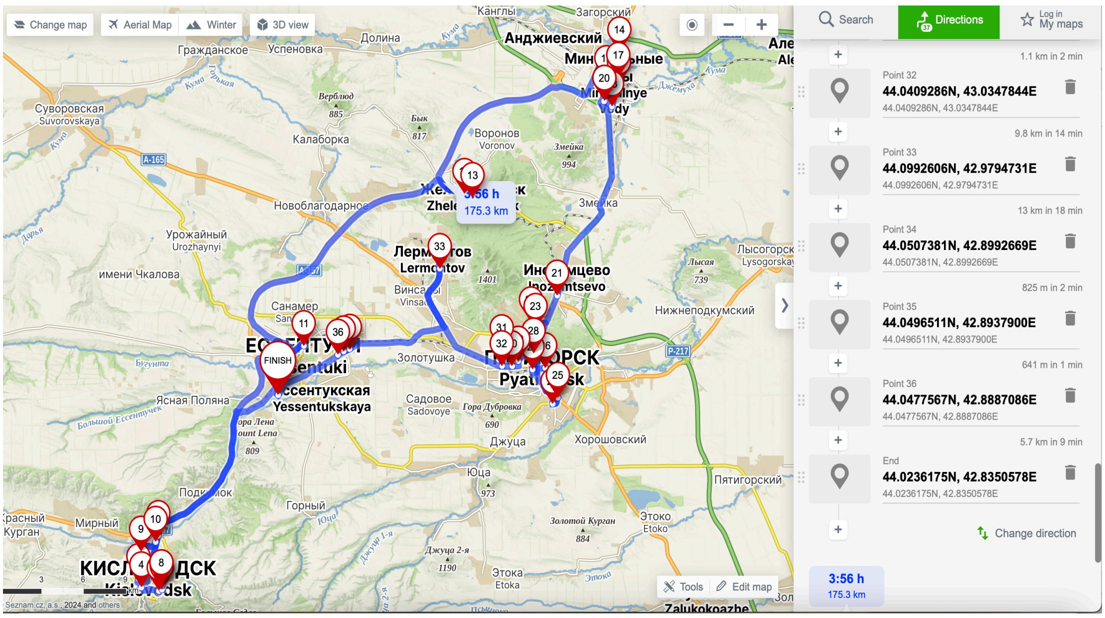
The table (9) shows the overview of all methods tested in the software. The Savings algorithm showed a significant difference between the other methods and gave the solution that equals 175673 meters or (175.673 km).

Meanwhile, around Mineralniye Vody region 75550 meters or (75.550km) around Stavropol. The result in table (9) demonstrates that in both areas Mineralniye Vody and Stavropol, the method that showed advanced route distance minimization is the Savings algorithm (parallel). The Savings algorithm is unique in flexibility and adjustability. In contrast to other approaches, which are limited by specific frameworks, the Saving algorithm adopts the complexity of the current problem. The data that "Tulip" has shared is a complex dataset that has a lot of delivery points and covers a big area. Nevertheless, the Savings algorithm was able to bring the quick calculations and allow us to move quickly across the complexity of this issue.

The saving algorithm has delivered the solution to the problem in Mineralniye Vody, by creating the stop order across the towns in this region and returning to the starting point. The cycle that software calculations of the Savings algorithm has provided the following order:

[E3]-[F10]-[F4]-[F5]-[F6]-[F7]-[F9]-[F8]-[F1]-[E5]-[B2]-[B1]-[A1]-[A6]-[A3]-[A2]-[A4]-[A5]-[A7]-[C2]-[D5]-[D4]-[D6]-[D11]-[D3]-[D10]-[D7]-[D9]-[D1]-[D8]-[D2]-[C2]-[C1]-[E1]-[E2]-[E4]

Picture 8 Savings algorithm(parallel) representation on the map, Mineralniye Vody



Source: own work based on the data provided by Tulip.

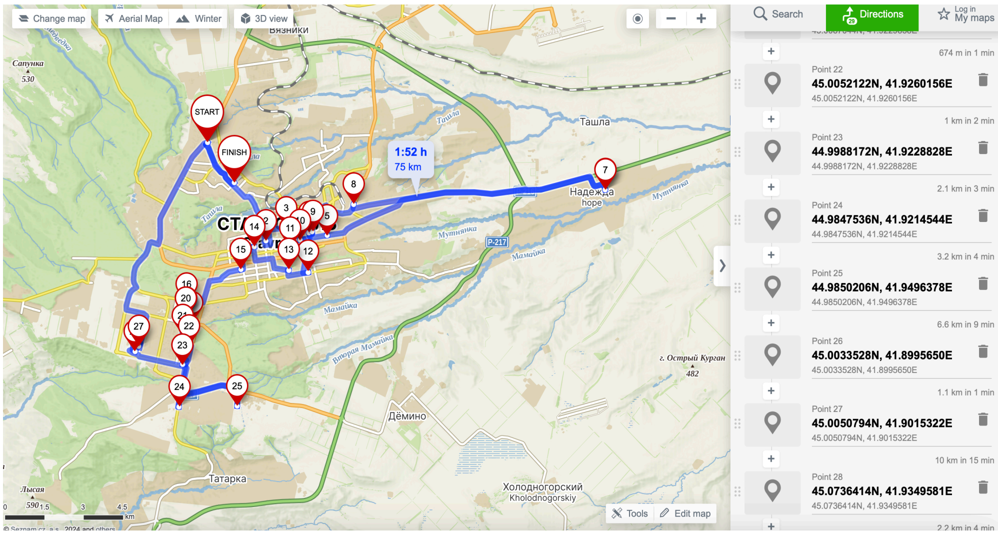
Picture (8) is a graphical representation of the area of Mineralniye Vody and the retail location of the map. The order that has been developed with the use of the software is a connected optimized route between Mineralniye Vody and its surroundings. The time that it will take to deliver flowers to all retailers is decreased compared to the current one and equals 3.56h or (236 min).

Following the distribution plan of the company “Tulip”, the next region where flowers are delivered in Stavropol. The network that “Tulip” works with consists of 32 retailers. Some of them are located within the same address, and they would be counted as one when implementing the TSP solution.

After performing calculations with the help of software and with the implementation of the Savings algorithm for Stavropol, the optimized solution is:

[S34]-[S3]-[S2]-[S30]-[S32]-[S36]-[S17]-[S16]-[S31]-[S22]-[S23]-[S1]-[S18]-[S28]-[S12]-[S21]-[S20]-[S13]-[S26]-[S10]-[S7]-[S6]-[S5]-[S19]-[S25]-[S11]-[S35]-[S33]

Picture 9 Savings algorithm (parallel) representation on the map, Stavropol



Source: own work based on the data provided by Tulip.

Picture (9) represents the locations of the retailers around the Stavropol region. The numbers indicate the order in which shops will be visited graphically. The optimized route will be 75 km long and will take 1.52h, which equals 112 min.

Table 10 Results after the implementation of the Savings algorithm

Region	Distance before opt. (m)	Distance after opt.(m)	Time before opt. (min)	Time after opt. (min)	Difference(m)	Difference (min)
Min Vody	342880	**175673**	532	236	167207	296
Stavropol	247140	**75550**	443	112	171590	331

Source: own created

Table (10) shows how the time and distance changed in both regions after the calculations in the software using the Savings algorithm. The time has been reduced by 296 min. in Mineralniye Vody and by 331 min. in Stavropol, distance has shortened by 167207 meters in Mineralniye Vody and by 171590 in Stavropol.

The difference between the optimized and not optimized distances in percentage can be expressed as:

$$Difference\ between\ \ distances\ (\%) = \frac{342880 - 175673}{342880} X\ 100 = 48.7\%$$

$$Difference\ between\ \ distances\ (\%) = \frac{247140 - 75550}{247140} X\ 100 = 69{,}4\%$$

The difference in table (10) shows that the result has improved by 48.7% for Mineralniye Vody and 69.4% for Stavropol.

“Tulip” increased production of retails sales in recent years and due to that reason delivery and logistics have become one of the priorities these days. Now company owns two cars that can be used for deliveries. However, they implement only one due to saving costs. Because the number of flowers demanded is higher than the quantity that could be fitted in one car, the delivery must be four times a week, two times in Stavropol and twice in Mineralniye Vody. It is necessary to connect the demand for flowers with the supply chain logistics. Table (11) below shows the supply of flowers for the months from 29.09.23 to 03.03.24. The highest demand is on 29.11, which is Women’s Day in Russia, 14.02 an International Valentine’s Day, and 8.03 when is International Women's Day.

According to the current situation, the Peugeot partner is the only vehicle in use, with a capacity of 5000 flowers maximum per loading and one way. The table (11) below shows the harvesting and sales periods. It will cover the sales “Tulip“ has provided in the year report. The detailed table that was provided will be presented in the abstract. One package contains 50 tulips at regular base.

Table 11 Supplied number of flowers in Mineralniye Vody

Dates	Total flowers order (N)	One car max capacity (per day)	Number of cars needed
27.09.2023	5350	5000	2
01.10.2023	5450	5000	2
04.10.2023	5000	5000	1
07.10.2023	5900	5000	2
01.11.2023	11450	5000	2
23.11.2023	12150	5000	2
29.11.2023	9000	5000	2
13.12.2023	2575	5000	1
12.02.2024	9300	5000	2

Total sold for 29.09.23 to 03.03.2024 in Mineralniye Vody to retails	**331 675 tulips** **6634 packages**

Source: own work

The table (11) demonstrates the random variety of dates, during the season and expresses that current logistics approach is inefficient. The demonstrated table highlights the need for a second car, which would not only allow reducing the number of trips per current though optimized routes but also to increase customer satisfaction level by increase the on-time delivery rates. "Tulip" currently serves around 80 retails, by one season in one region around 331676 tulips needed to be delivered and dependence only on one vehicle does not decrease costs but makes it more expensive and inefficient.

Changing the approach of using one car only increases the potential to transform the current logistics approach. A considerable decrease in the number of trips required by utilizing the combined capacity of two trucks will simplify the delivery and improve operational effectiveness.

Table 12 Supplied number of flowers in Stavropol

Dates	Total flowers order (N)	One car max capacity (per day)	Number of cars needed
28.09.2023	4450	5000	1
03.10.2023	1450	5000	1
05.10.2023	4800	5000	1
08.10.2023	5950	5000	2
03.11.2023	5450	5000	2
21.11.2023	7200	5000	2
1.12.2023	3550	5000	1
12.12.2023	4500	5000	1
11.02.2024	12100	5000	2
Total sold for 29.09.23 to 03.03.2024 in Stavropol to retails		**265 575 tulips** **5312 packages**	

Source:own work

Table (12) demonstrates that the quantity of supplied flowers exceeds the capacity of one car. The random allocation of dates that were taken from the full report provided by “Tulip” shows that the second car must be used to meet delivery demand. It is visible that on many occasions, even when it is not yet close to certain holidays the demand already exceeds the capacity.

The difference of 48.7% for Mineralniye Vody and 69.4% for Stavropol shows that route optimization significantly reduced the total distance traveled. The optimization already makes it possible to travel more efficiently. However, the company may now implement more frequent deliveries because of the optimized routes and implementation of second vehicle. Due to the capacity limits, the company tends to perform two-day delivery cycles for each destination per week. Since the route has become shorter, second car implementation would be additional improvement for company logistics, as now the flower delivery cycle can be more efficient and faster as to only two deliveries per week. That reduction leads will still lead to customer satisfaction, because a second vehicle will allow to delivery of the ordered number of flowers at once, moreover, with that approach the late delivery rate tends to decrease, which will enhance customer satisfaction and trust. The threats to this can be unpredictable situations like weather extreme conditions or car damage, however, those are rare things to happen.

4.5 KPI’s

One of the most useful calculations that can measure the success of the company is KPI. In the current thesis, two significant KPIs will show the on-time delivery rate and average time of deliveries. The formula for on-time delivery rate provides important information about the dependability and consistency of delivery services.

It is measured as the ratio of deliveries performed on scheduled time divided by a total number of deliveries.

“Tulip” has provided details on their delivery situation. The table below shows the overview of the situation that currently the firm experience. Most of the delays were not caused by unexpected to uncontrolled conditions, such as weather conditions or car problems, but were caused by ineffective schedule and not optimized routes between the company and retailers.

The delivery is still counted as “on time”, even if the order arrives within the first ten minutes after the planned time. The table follows the order before optimization.

This table contains only official data that “Tulip” has provided. Three days has been chosen following different scenarios.

Table (13) shows current deliveries, which, in many cases, are delayed. Though the table doesn’t provide all-season observation on thirty-six shops in Mineralniye Vody, and on each day the delivery has been performed, the sample allows us to observe the delivery on the first three nodes of the route because if the delay happened at the beginning of the route, it leads to the overall delay in the whole journey during the day, the days have been chosen according to the regular dates (the date which is not connected to any holiday), a regular day with the most of orders on regular demand, such as 1.11.23, one day that is Mother’s day and the last day is pre-holiday date before Valentine’s day. That sample provides necessary observation and let us to perform calculations and see the on-time delivery rate to those dates:

Table 13 Overview of ythe delivery situation in Mineralniye Vody

Date	Shop	Scheduled time	Actual time	On time/no
27.09.23	F5	10:00AM	10:45AM	NO
	D2	10:30AM	11:25AM	NO
	D1	11:00AM	11:45AM	NO
1.11.23	F5	10:00AM	10:07AM	YES

	D2	10:30AM	10:35AM	YES
	D1	11:00AM	11:30AM	NO
29.11.23	F5	10:00AM	10:14AM	NO
	D2	10:30AM	10:34AM	YES
	D1	11:00AM	11:10AM	YES
12.02.23	F5	10:00AM	10:10AM	YES
	D2	10:30AM	10:55AM	NO
	D1	11:00AM	12:00PM	NO

Source: on created based on the data provided by "Tulip"

$$On\ time\ delivery\ rate = \frac{Number\ of\ on-time\ delivery}{Total\ number\ of\ deliveries}\ X\ 100$$

$$On\ time\ delivery\ rate = \frac{4}{12}\ X\ 100 = 33.3\%$$

The one-time delivery rate demonstrated that only around one-third deliveries has been completed within the time limit. Given the low rate, it can express that the company is facing difficulties with the logistics aspect and problem with the delivery procedure.

Such a low percentage of on-time deliveries can indicate that businesses have difficulty keeping up with customers' expectations. Poor on-time delivery performance can lead to a loss in customers and their complaints, which can affect business success, loss of revenue and ROI. In some cases, it can seem that a few minutes doesn't change the whole picture. However, when the lateness becomes a regular tendency, that led to complaints and dissatisfaction.

To analyze Stavropol delivery performance, the same sample of dates and shops has been chosen to be able to be compared fairly. Choosing the same sample shows that any differences observed are not due to different chosen samples, rather they correspond to the real variances in consumer demand or operational efficiency.

The analysis for Stavropol in Table (14) included the exact dates and the same retailers that regularly attended at the beginning of the delivery cycle. They have been chosen as a sample and dates has been chosen as per previous table, regular date, highest demand, pre-holiday, and holiday time.

$$On\ time\ delivery\ rate = \frac{6}{12}\ X\ 100 = 50\%$$

The on-time delivery rate shows higher result then the one in Mineralniye Vody, however have only 50% of orders delivered on time is still not the best option for a company like "Tulip", especially at the beginning of being successful and recommending themselves to the customers.

Table 14 Overview of the delivety situation in Stavropol

Date	Shop	Scheduled time	Actual time	On time/no
27.09.23	S7	10:00AM	10:27AM	NO
	S14	10:30AM	11:15AM	NO
	S1	11:00AM	11:55AM	NO
1.11.23	S7	10:00AM	10:05AM	YES
	S14	10:30AM	10:40AM	YES
	S1	11:00AM	11:10AM	YES
29.11.23	S7	10:00AM	10:10AM	YES
	S14	10:30AM	10:34AM	YES
	S1	11:00AM	11:03AM	YES
12.02.23	S7	10:00AM	10:15AM	NO
	S14	10:30AM	10:50AM	NO
	S1	11:00AM	11:47AM	NO

Source: own created based on data provided by "Tulip"

That on-time delivery rate enhances the importance of implementing a second vehicle and following a new optimized route that would decrease the time and number of deliveries per week. By implementing two cars, the company can be in two cities simultaneously. In contrast, one car could be directed to Min. Vody and another to Stavropol if the orders are not higher than the capacity of one car per region. In case it is, two cars can be directed to both of the regions, which will provide all orders delivery on time and at the same day, and decrease the number of deliveries per week from four to two.

The optimization method and implementation of the savings algorithm have decreased average time delivery significantly.

Before the implementation the average delivery time was:

$$Average\ delivery\ time = \frac{532 + 443}{4\ (per\ week)} = 243{,}75\ min$$

After the implementation of the new routes and optimization process:

$$Average\ delivery\ time = \frac{236 + 112}{2\ (per\ week)} = 174\ min$$

Following the execution of the new routes and optimization plan while implementing the second vehicle, the business tends to make two weekly deliveries, one to each region. It is determined that the new weekly average delivery time is 174 min.

This shows that delivery efficiency has significantly improved, as the weekly average delivery time has decreased from 243 minutes to 174 minutes. This positive change was influenced by implementing the Savings algorithm and the other vehicle.

4.6 Future plan for Tulip Company

“Tulip” is a growing company that plan to add ten new retailers for each region by October 2024, currently the new clients are being added to the main database with orders for the next harvesting season. Such expansion of business both creates challenges and opportunities, and the need for an efficient supply chain arises again. Therefore, taking into account the importance of efficient delivery starting from these days will directly contribute to the success of next season.

The company has shared future client datasets, which will allow to prepare the efficient, optimized route for delivering flowers even for the next season. Twenty additional clients will surely influence current logistics, therefore, the implementation of TSPKOSA with additional clients’ networks would make a huge difference in “Tulip” market share.

Table 15Next season scheduled customers for "Tulip" in Mineralniye Vody

Name of the customer	City	Address
D12 Na Romashke	Pyatigorsk	Ordzhonokadze 2
D13 Luludi	Pyatigorsk	Kozlova 39L
D14 111 Roz	Pyatigorsk	Admiralskogo 6B
D15 7 Roz	Pyatigorsk	Shirokaya 47
D16 Flowers	Pyatigorsk	Kuybisheva 42
F11 El-flowers	Kislovodsk	Dvadenko 2
F12 Cvety 1803	Kislovodsk	Pervomayskiy 10B
E7 Cvetkoff	Essentuki	Pyatigorskaya 119B
E8 Amore	Essentuki	Oktyabrskaya 442 A
E9 Magiya Cvetov	Essentuki	Oktyabrskaya 314
E10 Black tmin f.	Essentuki	Ermolova 98/1
E11Moysidis flower	Essentuki	Nikolskaya 29

Source: own work, based on data provided by Tulip

The table (15) represents new addresses that “Tulip” company is planning to expand its network by the autumn of 2024. The left column significs the identifier of place, in current table it starts from D12-D13-D14-D15-D16-D17, due to this being set as additional customers to the existence ones in Pyatigorsk. Same as for Kislovodsk for F11 and F12, and then for Essentuki as E7-E8-E9-E10-E11.

Stavropol is gaining additional twelve customers by the next season. They are in the table below.

Table 16 Next season scheduled customers for "Tulip" in Stavropol

Name of the customer	City	Address
S37 Flora K	Stavropol	Rogozhnikova, 27
S38 Flowers and You	Stavropol	Tukchachevskogo, 24/2
S39 Buket na vkus I cvet	Stavropol	General Margelov,9/1
S40 Summer	Stavropol	Pirogova 5A/7
S41 Alex Troides	Stavropol	Shpakovskaya 111/4
S42 Party Flowers	Stavropol	Lev Tolstoy, 121A
S43 Flower and Tochka	Stavropol	Serova 97
S44 Arm Flowers	Stavropol	Serova 302
S45 Cvety for you	Stavropol	Lermontova 187
S46 Alenkiy cvetochek	Stavropol	Dzerzhinskogo 158
S47 Ofeliya	Stavropol	Mikhail Morozov 10
S48 Markiza	Stavropol	Goleneva 41

Source: own created, based on the data provided by Tulip

Table (16) for Stavropol represent the identifier S, S37-S48 indicates the same region and will be an additional point within this region for next season.

The business expansion for “Tulip”, is a big thing. Though the business is still tiny, new twenty-four retails is a big chance for a company to recommend itself. One way to gain customers' trust and loyalty is to perform deliveries on time since the early start of the season. Therefore, the idea was to create optimized routes between the company and its clients, including additional new customers.

At the beginning of the process, before any of the calculations have been made, the table of coordinates must be turned into the distance matrix table that will include also new nodes, after that the calculations can be done with choosing one of the methods. It is required to test them all to be able to get the closest to the optimal solution.

Because the table is now expanded, the performance of Branch and Bound cannot bring valuable solutions, due to even bigger matrix size.

Table 17 The results TSPKOSA including additional customers

Method	Result Stavropol region (m)	Result Mineralniye Vody region (m)
Nearest Neighbor Algorithm	93778	187423
Vogel's approximation method	88172	221021
Savings algorithm (parallel)	**83801**	**180710**

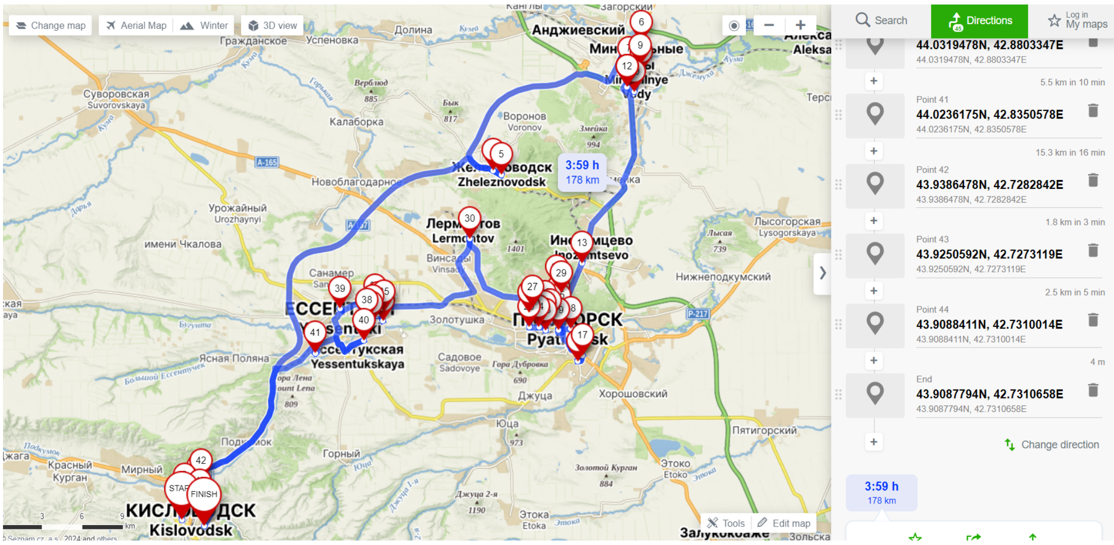
Source: own calculations based on the results from TSPKOSA.

Table (16) includes twenty-four new locations and provides results based on calculations of Nearest neighbor algorithm, Savings algorithm, and Vogel's approximation method. The result shows that Vogel's approximation method works better when the scale of the problem is smaller. However, the solution that is the closest to optimum was obtained with the Savings algorithm. This method showed that it is going to take 180710 meters or (180.710km) for a cycle of delivery in Mineralniye Vody region and 83801meters or (83.801km) in Stavropol region.

The savings algorithm has provided the solution for the Mineralniye Vody region, which offers to attend retail in the following order:

[F4]-[F2]-[F1]-[B2]-[B1]-[A1]-[A6]-[A3]-[A2]-[A4]-[A5]-[A7]-[C2]-[D12]-[D7]-[D6]-[D11]-[D3]-[D10]-[D15]-[D16]-[D9]-[D13]-[D1]-[D2]-[D8]-[D14]-[D5]-[D4]-[C1]-[E7]-[E8]-[E2]-[E11]-[E1]-[E4]-[E10]-[E9]-[E5]-[E6]-[E3]-[F10]-[F11]-[F8]-[F9]

Picture 10 Savings algorithm map for graphical representation, Mineralniye Vody



Source: own created based on mapy.cz

The picture (10) defines the order in which vehicle attend shops graphically. The time that the car will be delivering flowers equals to 4 hours (240 min). The route is optimized and contains of new locations of the retails. Compared to the current season route, which has been previously optimized, the additional shops have increased distance by 5037 meters (5 km).

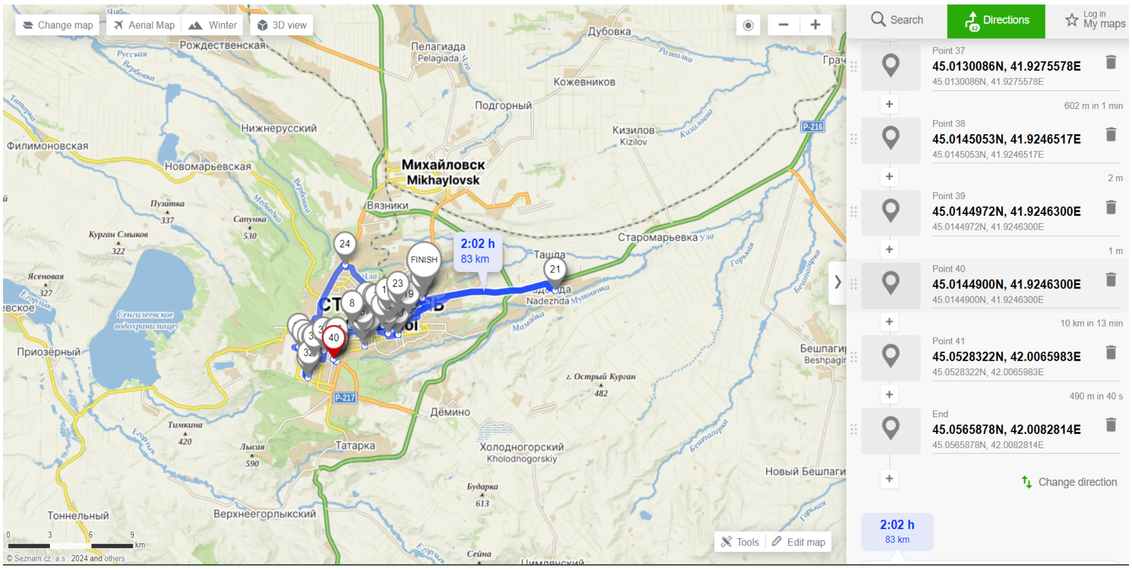
$$\% \, difference = \frac{180710 - 175673}{175673} X \, 100 = 2.87\%$$

The delivery distance rose by approximately 2.87%, from 175,673 metres to 180,710 metres, after 12 stores were added to the map.

Following to the next region, the Savings algorithm again showed the best results of all methods and proposed next delivery order:

[S42]-[S43]-[S21]-[S12]-[S46]-[S47]-[S3]-[S12]-[S44]-[S18]-[S28]-[S45]-[S1]-[S23]-[S22]-[S2]-[S31]-[S30]-[S32]-[S36]-[S17]-[S16]-[S48]-[S34]-[S39]-[S24]-[S14]-[S29]-[S27]-[S38]-[S37]-[S35]-[S33]-[S15]-[S40]-[S20]-[S41]-[S13]-[S26]-[S10]-[S7]

Picture 11 Savings algorithm TSPKOSA graphical representation for Stavropol



Source: own work based on mapy.cz

Picture (11) means that the route across the Stavropol will take around 2:02h (122 min), while the additional customers increased the delivery area by 8251 meters (8 km).

The graphical representation navigates through the area and shows the scale of it. Stavropol is city that is surrounded by mountains and hills road. Due to that reason, time can be slightly changed while traveling.

The percentage difference is:

$$\%\ difference = \frac{83801 - 75550}{75550} X\ 100 = 10{,}9\%$$

The formula above means that the delivery distance rose by approximately 10,9%, from 175,673 meters to 180,710 meters, after 12 stores were added to the map.

KPIs will be calculated for both areas and will continue to follow the plan of additional vehicle implementation, therefore the delivery will be performed two times per week.

$$Average\ delivery\ time = \frac{240 + 122}{2\ (per\ week)} = 181\ min$$

According to the calculations of KPI, the average delivery time has reduced from 243. 75 min to 174 minutes after the implementation of the Savings algorithm optimization that was performed in TSPKOSA software. This time reduction led to the conclusion that the delivery plan is now more efficient and lead to cost savings.

Nevertheless, the average delivery time has increased after additional implementation of the location per the company's future, and it is still below the time spent before the optimization.

Additionally, the optimization strategies influence business, as a competition on market is high, the effectiveness and quickness of the process bring to more customer satisfaction, that lead to expansion of the customer base in the future, increased sale, and market share.

5. Results and Discussion

Within the supply chain of the flower business of the company “Tulip”, located in Kochubeevskoe, many troubles with logistics implementation have been noted. Constant late deliveries, only one third delivered flowers have been on time. Since the company has been concerned about growing and expanding, the delivery problem must have been searching for a solution long ago.

Logistics is one of the top priorities in any business; the constant globalization and industrialization affect world changes and lead to continuous improvements in the logistics sphere. “Tulip” company is not yet such a big business, but it already has around one hundred customers planned for next season. Therefore, bringing logistic value for this company and improving its distribution is a significant deal.

The objective was to evaluate the current logistics, define problems in this area, find out challenges and limitations, and develop as closest as it could be to be optimized transportation route network. The distances were measured with a help of advanced software for travelling salesman problem solution, TSPKOSA.

The approach was to put into practice the information that was provided by the company and use it to bring some value back. The idea was to gather necessary information as coordinates by using Mapy.cz, locations, customers, volume of sales, and so on. Different methods in the software have analyzed the required information before the calculations of KPIs has been done.

The data that company provided contained the delivery times, the number of flowers sold per day, which made it possible to have an overview on tulip industry, knowing the history of this flower back in centuries, and business itself.

The findings has shown significant improvement in the distance shortage by 48,7% for Mineralniye Vody and 69,4% for Stavropol. The average delivery time has been reduced from 243,75 minutes to 174 minutes, and from four times per week, delivery has been reduced to only two times. Depending on the number of orders, the second vehicle can increase efficiency, as one of each could travel to different regions simultaneously by using optimized route. That way the cycle is shorten, and in case of big orders that would not fit into one car, two cars can be travelling to the same destination and back at the same day in a shorter time, which potentially can visit two regions simultaneously possible, in times of high demand such as holidays and seasonal demands.

The plan of the company to implement another twenty-four shops in two regions has been also analysed and the TSP KOSA optimization method. That has been done to cut the distances and prepare for a company future optimization solution for the upcoming season. Though, the time and distance travel potentially increased, it still stays lower than the initial cycle of delivery, which required much more time, fuel costs, labour costs and other expenses connected to the longer distances.

The theory part has accurately described how many different methods exist to be able to perform different calculations in the sphere of logistics, it showed that many of those methods still have some limitations either due scale of the problem, or missing data. One of the methods that in this thesis had already limitations even with this number of retails is Bench and Bound method, widely known for its successful and valuable calculations. The disadvantage of such a method has been defined very fast, as this distance matrix has already been too long, even before new shops have been added to it. Therefore, this can indicate that if the company plans to grow, obtain new customers, expand to new regions or even countries, and when the dataset of nodes is large, the BB method is unreliable, as it will not be able to solve large problems.

The method that this thesis used was the Savings algorithm, which took time longer than others to provide the solution, however comparing to the Nearest Neighbor method and Vogel's approximation method the result has been better.

The Vogel's approximation method, though, provides a better solution as the problem gets shorter. This was shown when comparing the results of Vogel's approximation method in two regions, which differed in retail numbers.

Overall, the methods have shown their reliability and have led to shorter distances, reducing fuel and labor costs. Though the two vehicles are now implemented, each driver will have to make a cycle once a week, compared to one driver who must do four times deliveries per week. The other idea was to enhance the satisfaction level of customers. The customers that trust most likely will become loyal customers, that is on this stage of the business development is one of the pivotal tasks to be able to increase market share and volume of the business. The capacity has been also increased as now more flowers can be delivered at the same time, therefore no need to split one order in two days for delivery. Additionally, second vehicle can be a great back up in extreme situations or unpredictability.

Other limitations must be noted, those include the sensitivity of TSPKOSA algorithms, it would need a lot of connections and can potentially be very complex with such things as what are the delivery priority or vehicle capacities and the decision how to create matrix in the right way so it could deliver valuable solutions. Therefore, when a large dataset can include thousands of locations, those calculations might be challenging to perform. Firstly, to be able to make calculations in the TSPKOSA, searching for coordinates is not enough. It must be represented as a distance matrix, which can take longer time to create. Because of this, the optimization may become time-consuming and complex, especially demanding time and effort in the real-time situations.

Implementing any type of software potentially would be investment, and very complex software that is used in big companies or large businesses usually costs a lot of money, implementing TSPKOSA in some large-scale businesses might not bring any significant or expected results.

From an economic perspective, this research emphasizes how strategic planning and technology investment and priority separation make a huge difference. It also highlights how critical it is to be flexible and agile to adjust to shifting consumer demands and market conditions.

Some of the recommendations for the company Tulip would include prioritizing the delivery on time and paying attention to supply chain management. If the plan is to grow the business, this aspect must be paid attention to more carefully.

Additionally, to examine ways to provide the dynamic route optimization and real time adaptation to some unpredictable situation. The calculation performed in the thesis might not have a solution for such problems as traffic conditions or unpredicted weather conditions. Therefore, considering those factors can potentially lead to successful business, customer satisfaction of on-time deliveries and increase of client base. If Tulip would be interested in further implementation of the TSPKOSA or other software that can calculate the distances and optimize the routes, it would be essential to educate the staff and get certain knowledges in this field, that would be efficient to also hire person who would be responsible for logistics. Establishing constant control on KPIs will help control some areas of the business and track the company's performance, to find opportunities for more optimization and refinement, regularly assess the performance of optimized routes in terms of cost savings, efficiency gains, and customer satisfaction.

This thesis does not cover one exact discipline, it consists of many, from economics to statistics, from finance to management, because successful business always includes all spheres inside. This thesis is a real example of expanding company and the challenges they are facing.

6. Conclusion

In summary, the analysis of the supply chain of the Tulip has been performed and showed quite a problematic situation, it has shown that the company didn't consider logistics as their priority currently and therefore had a lot of costs that was extra due to few reasons, and the simplest one was how much it was spend on gasoline, by driving extra cycles and kms without real need.

This research has yielded useful insights and recommendations for improving route planning and execution procedures. These were achieved by a comprehensive analysis of existing supply chain dynamics, evaluation of key performance metrics, and deployment of sophisticated optimization techniques.

The results of this study have shown a lot of progress and defined such optimized routes that would bring more efficient and fast deliveries, it would save fuel cost but still be able to use second vehicle, deliver more flowers at the same time as production is still growing, be able to measure KPI and have constant control of the situation and increase customer satisfaction.

The main achievement of this diploma thesis has been to demonstrate how the chosen method and the software that operates in excel and doesn't require complex algorithms could improve the company's position in the supply chain industry. The goal of shortening distances, implementing the second vehicle and desired increase of on-time deliveries have been achieved.

TSP KOSA is a powerful tool that can help smaller local companies optimize routes that will have influence on many aspects of business in the long run. Still, it is essential to understand and evaluate the limitations and costs in case "Tulip" will plan to implement software that could deliver solution for the shortest and efficient delivery route combinations.

All things considered, this work can be used as the groundwork for future investigations and learning about the nuances of route optimization in the context of flower supply chains. "Tulip" can continue constant improving and provide outstanding value to its customers by implementing this research findings into practical real-life experience while research for advance methods and new technologies especially in the field of logistics.

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Appendix

A (Минеральные Воды) Mineralniye Vody			S (Stavropol)		
A1 (Лена Левокумка)Lena Levokumka	44.22937239031017, 43.13999439557137	Levokumka, Mostovaya 53/4	S1 ILONA FLORA FANTASY	45.03809980604509, 41.97556513795609	Stavropol, st. Mira, 274
A2 (Маша Анжиевского) Masha Anzhevskogo	44.21405944287147, 43.13882823903143	Min.Vody, Anzhievskogo 4	S2 ANNA TSUM	45.04493150544660 6, 41.97368136864643	Stavropol, Dzerzhinsky street, 106
A3 (Галя Минводы Рынок) Galina M.Vody market	44.20984431039009, 43.13957649371636	Internacinonalnaya 37, Min.Vody	S3 SASHA PUSHKINSK RINOK	45.040526898005304, 41.96367015330119	Stavropol, st. Pushkina, 8A
A4 (Яна Минводы) Jana Min.vody	44.19684964825135, 43.133251480224104	Mineralnye Vody, prosp. 22nd Party Congress, 133B	S4 MISHA PUSHKINSKIY RINOK	45.040526898005304, 41.96367015330119	Stavropol, st. Pushkina, 8A
A5 (Лена Минводы) Lena Min Vody	44.200337543902464, 43.12640235324189	Mineralnye Vody, st. 50 years of October, 46A	S5 ALENA OK	45.00521208581309, 41.926015237953735	Stavropol, st. Dovatortsev, 61
A6 (Марина Пролетарская 23) Marina	44.212208871733125, 43.12817588022525	Mineralnye Vody, Proletarskaya 23	S6 LUDA 50 LET VLKSM	45.008704729926166, 41.922985939807695	Stavropol, st. 50 years of Komsomol, 32A
A7 (Ольга 7роз) Olga 7 roses	44.20027601129З, 43.12633798022445	Mineralnye Vody, st. 50 years of October, 46A	S7 IRA TUHACHEVSKIY RINOK	45.01448990795566, 41.924629453299346	Stavropol, street 50 let VLKSM, 16I
B (Железноводск)			S8 SASHA TUCHACHEVKSIY RINOK	45.01448990795566, 41.924629453299346	Stavropol, street 50 let VLKSM, 16I
B1 (Наталья) Natalia	44.14189445759665, 43.00882563789279	Zheleznovodsk, st. Lenina, 104A	S9 NATALIA PETROVNA TUHACHEVSK	45.01448990795566, 41.924629453299346	Stavropol, street 50 let VLKSM, 16I
B2 (Марина) Marina	44.14450124956893, 43.00135642440175	Zheleznovodsk, Lenina 165	S10 NATALIA TUHACHEVSK RINOK	45.01449749246891, 41.924629453299346	Stavropol, street 50 let VLKSM, 16I
C (Лермонтов и Иноземцево)			S11 NATALIA TATARKA	44.98502086685845, 41.94963805329726	Stavropol, street named after the Soviet Army-2, 65
C1 (Ксюша) Ksusha	44.099260656853, 42.979473197415956	Lermontov, ave. Lermontova, 29	S12 SERGEI DARI CVETI	45.036477987137445, 41.94159415330088	Stavropol, st. Lenina, 392
C2 (Иноземцево Рынок) (Inozemtsevo market)	44.083277655626325, 43.08432432335263	st. Gagarina, 207, building 1, Inozemtsevo town	S12 KATYA FLORA KONTORA	45.03853391819497, 41.958017264938654	Stavropol, st. Lenina, 318/2
D (Пятигорск)			S13 RAYA YUNOST	45.01300891128996 5, 41.92755708028186	Stavropol, st. Tukhachevsky, 23/1
D1 Маша Перья (Masha P)	44.04084446811204, 43.04380778392053	Pyatigorsk, st. Mira, 178	S14 ANGELIKA CVETOCHNIE LUDI	45.01822349326278, 41.896819733989545	Stavropol, st. Tukhachevsky, 27/1
D2 Аревик (Arevik)	44.04092830597797, 43.03478396486833	Pyatigorsk, st. Mira, 248	S15 ALENA FLOER	45.01557254307586, 41.90633201097186	Stavropol, st. Tukhachevsky, 24/1
D3 Виолетта Пятигорск (Violetta)	44.03966497149804, 43.07365142624798	Pyatigorsk, st. Dzerzhinsky, 35	S16 DMITRY ZAVODSKAYA TUHACH	45.05283204214861, 42.00659896679336	Stavropol, Zavodskaya 11
D4 Ксюша (Ksusha 1)	44.063319069045875, 43.06487091645373	Pyatigorsk, st. 295th Infantry Division, 2A, p. 2	S17 ANATOLY MICHAILOVSK	45.05764241424821, 42.129658739811155	Shosseynaya street, 22, Mikhailovsk, Shpakovsky municipal district, Stavropol region
D5 Инна (Inna)	44.06721629248408, 43.0608521047708	Pyatigorsk, st. 295th Infantry Division, 2A, p. 1	S18 ARMEN SEROVA	45.03026422671235, 41.98424728213676	Stavropol, Serova 302
D6 Гаяна (Gayana)	44.01815242365114, 43.08023628206534	Yutskaya st., 29, Goryachevodsky village	S19 OLGA KOSMOS	44.99881721645255, 41.922882326315694	Stavropol, st. 45th Parallel, 3B
D7 Нелли (Nelli)	44.04846318734036, 43.06318596857615	Pyatigorsk, ave. 40 years of October, 30	S20 NATALIA SALUT	45.019338400388804, 41.92482498028231	Stavropol, 50 years of Komsomol 5
D8 Костя Крокус (Kostya Krocus)	44.0504464711567, 43.03494476486904	Pyatigorsk, Essentukskaya st., 29D Slobodskoy Privoz shopping center	S21 REGINA	45.030890906308684, 41.95136886679179	Stavropol, 8 March street, 69, Stavropol
D9 Татьяна (Tatiana)	44.04365497135362, 43.04949281090326	Pyatigorsk, Komarova 35	S22 VIKA SOVREMENNIK	45.04068943001435, 41.98038337843008	Stavropol, st. Lenina, 228
D10 Зарема (Zarema)	44.038825798533004, 43.06231708206677	st. Kozlova, 29, Pyatigorsk	S23 IRINA ROZALUX	45.03960503863731, 41.983020364938696	Stavropol, st. Rosa Luxemburg, 38
D11 Камелия (kamelia)	44.0218765530911, 43.08485462253944	ave. Kalinina, 299A, Goryachevodsky village	S24 NASTYA RUMBA	45.0179643160626, 41.89901498028216	Stavropol, st. Tukhachevsky, 25/2
E (Ессентуки)			S25 TATIANA BELIY GOROD	44.98475367488968, 41.92145495329728	Stavropol, st. Dovatortsev, 88V
E1 Женя (Zhenya)	44.0507383040735, 42.89926716857638	Essentuki, Oktyabrskaya st., 458	S26 KATYA ORANGE TUCHACHEVS	45.01450507698115, 41.924650910971806	Stavropol, street 50 let VLKSM, 16I
E2 Анна (Anna)	44.04965089563931, 42.89378945137761	Essentuki, Oktyabrskaya st., 427	S27 ALEXANDER PRO BUKET	45.01605841418701, 41.901726780282075	Stavropol, st. Tukhachevsky, 28/1
E3 Ольга (Olga)	44.02361771953819 4, 42.835058197410596	Essentuki, Oktyabrskaya st., 337/1	S28 KARINA PARTIZANSKAYA 3	45.03092758858772, 41.97484609377442	Stavropol, Partizanskaya 3
E4 Елена (Elena)	44.047756703968034, 42.88870799555863	Essentuki, Oktyabrskaya st., 409b	S29 TATIANA TUCHACH 26/5	45.01526924391945, 41.90234772446314	Stavropol, Tukhachevsky 26/5
E5 Яна (Yana)	44.05301514368957, 42.8581183090503 4	Essentuki, Nagornaya st., 1	S30 LERA KOMSOMOLSKAYA 65	45.04325384317722, 41.98488008028394	Stavropol, Komsomolskaya 65
E6 Ольга Магия Роз (Olga Magiya Ros)	44.03194764172968, 42.88033532254012	st. Gagarina, 65, Essentukskaya village	S31 OLYA MAKOV CVET	45.04363531964678, 41.986683080284	Stavropol, st. Goleneva, 70
F (Кисловодск)			S32 OLYA NIZ SEROVA	45.04225916883432, 41.99364058399121	Stavropol, st. Lenina, 108
F1 Amina	43.93509151977095, 42.7257574667146	ave. Pobedy, 141, Kislovodsk	S33 YULIA SAVCHENKO ROGOZH	45.00507974336443, 41.901531680281245	Stavropol, st. A. Savchenko, 38, bldg. 9
F2 Kristina	43.92908887074918, 42.71275453787792	Kislovodsk, Krasivaya st., 36B	S34 KATYA TASHLA	45.07364150478916, 41.93495792446734	Stavropol, prosp. Kulakova, 51
F3 Olga	43.91493073099729, 42.719649853221796	Kislovodsk, Pobeda Avenue 12B	S35 NADEZHDA OTRADNAYA/ROGOZH	45.00335249313699, 41.89956543795364	Stavropol, st. Rogozhnikova, 27
F4 Asya	43.91272982268825, 42.710386639730494	Kislovodsk, st. Heroev Medikov, 10	S36 DENIS NATALIA STAV	45.05774342574175, 42.129722668647375	Shosseynaya street, 20, Mikhailovsk, Shpakovsky municipal district, Stavropol region
F5 Nasty	43.90754375434915, 42.713043437876394	Kislovodsk, st. Gorky, 9G	TOTAL		
F6 Natalia	43.90556920029966, 42.728397126238676	Kislovodsk, Dzerzhinsky Avenue 25			
F7 Katya	43.90635769949821, 42.73145369554879	Kislovodsk, Territorialnaya st., 1			
F8 Angelina	43.90884105734651, 42.731001080204045	Kislovodsk, ave. Dzerzhinsky, 45			
F9 Nadezhda	43.90877922110185, 42.73106545322146	Kislovodsk, ave. Dzerzhinsky, 45/1			
F10 Rita	43.93864786414017, 42.72828413787864	Kislovodsk, ave. Pobeda, 124B			

Маршрут 1 (КМВ) Продажи по датам в штуках

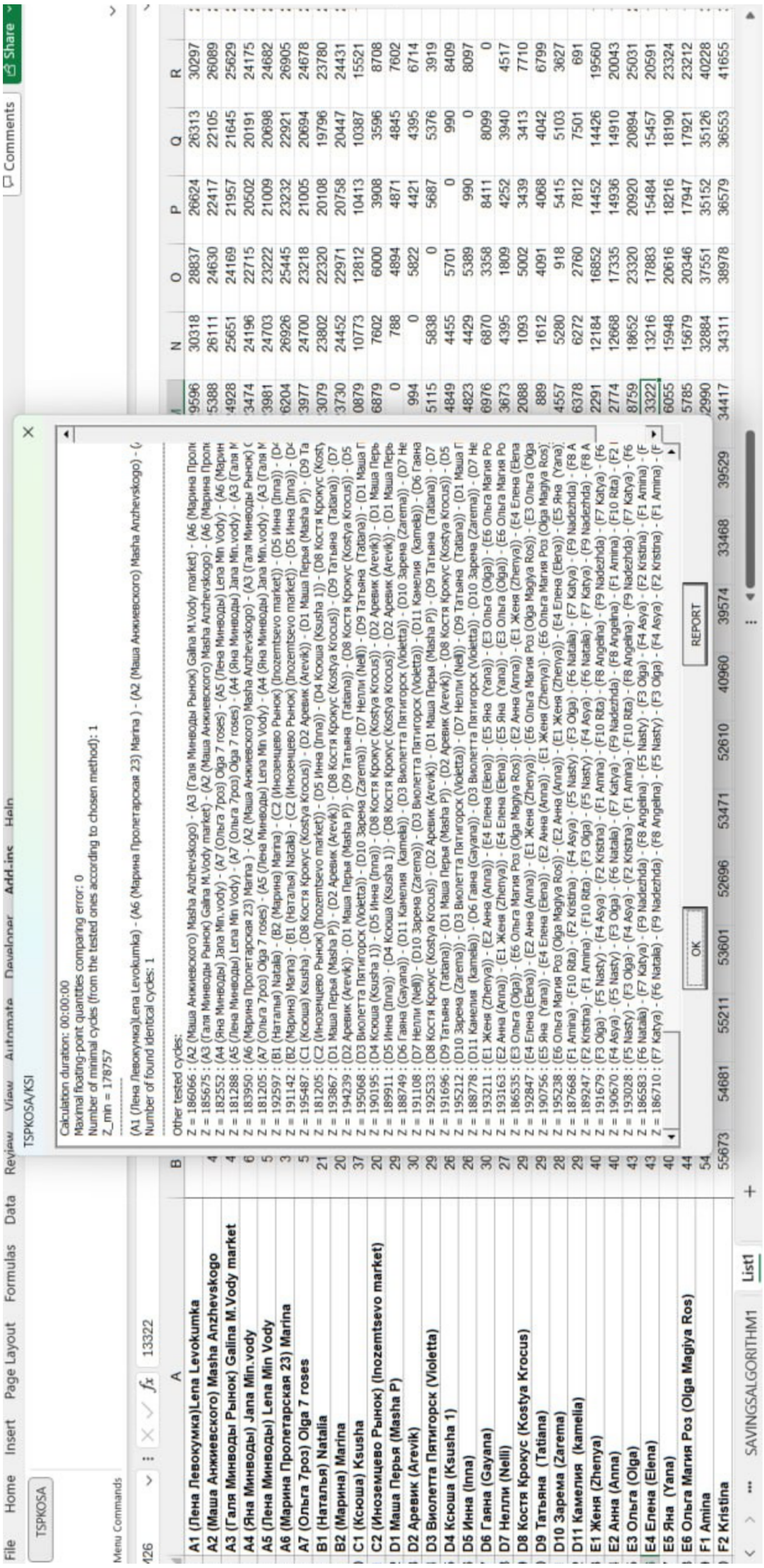
Город/Точка	27.09.2023	01.10.2023	04.10.2023	07.10.2023	11.10.2023	15.10.2023	18.10.2023	22.10.2023	28.10.2023	01.11.2023	04.11.2023	08.11.2023	11.11.2023	15.11.2023	18.11.2023
A (Минеральные Воды)															
A1 (Лена Левокумка)		150	100		150		100			100		50	100		100
A2 (Маша Анжиевского)		100	150												
A3 (Галя Минводы Рынок)		200	100	150	150		200	200		150				200	
A4 (Яна Минводы)		150			150										
A5 (Лена Минводы)															
A6 (Марина Пролетарская 23)			100		50		50	50		50		100	50		
A7 (Ольга 7роз)												600			
B (Железноводск)															
B1 (Наталья)	200	250	100				350		200			250		400	
B2 (Марина)	150		100		150		50			250				100	
C (Лермонтов и Иноземцево)															
C1 (Ксюша)	150	200	300		200		150	100	100		150	150	250	400	
C2 (Иноземцево Рынок)			250		300	50		350	250	300		200	150	250	200
D (Пятигорск)															
D1 Маша Перья	350	200	250	150	450	50	50	100	300	100	450	200	300	250	100
D2 Аревик	400		250		200										
D3 Виолетта Пятигорск	50	50	50	100		50	100	50	100		50	50		100	
D4 Ксюша		100	150	50	100			50	100		50	50	100	50	50
D5 Инна		150	50	250	200		100			100	50		150	100	100
D6 Гаяна			200		250						300	100		300	
D7 Нелли					300	400			750					600	
D8 Костя Крокус			400												450
D9 Татьяна		200			200					200		250		100	200
D10 Зарема		200					100		100				200		
D11 Камелия												100		300	
E (Ессентуки)															
E1 Женя	250	50	100	100				150						150	150
E2 Анна		100		50	50	50	50	50	50	100	50		100	50	50
E3 Ольга	100	100	50	150											100
E4 Елена															
E5 Яна				150	100		200				100	200			
E6 Ольга Магия Роз										200	150		200		
F (Кисловодск)															
F1 Amina	50							250			200				200
F2 Kristina	100														
F3 Olga	150		200		150		100				50		100		
F4 Asya	150	200		200	200	50		250	200			250	200		
F5 Nasty	200					150							200	50	
F6 Natalia			100	400							100	100	250	200	100
F7 Katya			100			50							150		
F8 Angelina	100		50				50								
F9 Nadezhda			50					150					100		
F10 Rita	100	50			50			50			100			100	150
	2500	2450	3200	1750	3400	850	1650	1800	2150	1550	1800	2650	2600	3700	1950

Город/Точка	22.11.2023	23.11.2023	25.11.2023	27.11.2023	29.11.2023	02.12.2023	06.12.2023	13.12.2023	13.01.2024	20.01.2024	27.01.2024	07.02.2024	11.02.2024	24.02.2024	27.02.2024	01.03.2024	02.03.2024	03.03.2024	04.0
A (Минеральные Воды)																			
A1 (Лена Левокумка)	250		100	200				25	50		100		200	1775				3800	
A2 (Маша Анжиевского)	300			100										650					
A3 (Галя Минводы Рынок)	400		200			400		250			250	500	550	3900					
A4 (Яна Минводы)														300					
A5 (Лена Минводы)			400			250		200			250			1100					
A6 (Марина Пролетарская 23)			100			50		50				150	550	1350				1500	
A7 (Ольга 7роз)			350			300	200						450	1900				13100	
B (Железноводск)														0					
B1 (Наталья)	750				250	250				150	100	150		3400					
B2 (Марина)	150		250		100				250				450	2000				2500	
C (Лермонтов и Иноземцево)														0					
C1 (Ксюша)			800	400	300	100	250		350	250	200	200	400	5400				7250	
C2 (Иноземцево Рынок)	450		250	700	300				50					4050					
D (Пятигорск)														0					
D1 Маша Перья	350		150	250			450	250	150		150	100	500	5650				8800	
D2 Аревик														850					
D3 Виолетта Пятигорск	250		350	100	100		100	100		50	50	50	300	2200				4000	
D4 Ксюша	50		300			50	100	50	50	50		200	250	1950				25000	
D5 Инна	350		1050					150						2800				3000	
D6 Гаяна			750	600		200	300				100	400	1500	5000				19150	
D7 Нелли			850			600				200				3700					
D8 Костя Крокус	2000													2850				1000	
D9 Татьяна	200		300	300			100	250						2300					
D10 Зарема	400		250											1250					
D11 Камелия			800	350	250							150	600	2550					
E (Ессентуки)														0					
E1 Женя			300		100	50								1400					
E2 Анна	100				100					50				1000					
E3 Ольга			200		100								200	1000					
E4 Елена											100	200	100	400				4550	
E5 Яна	500		150						200		500		300	2400					
E6 Ольга Магия Роз					100									650					
F (Кисловодск)														0					
F1 Amina		550		400					250					1900				5200	
F2 Kristina		300										100	950	1450				5500	
F3 Olga		1650					100		50	100	50		400	3100					
F4 Asya		900				50				250		450	1000	4350				8100	
F5 Nasty		2300		650			100			100		400	800	4950				5600	
F6 Natalia		450			150	250			100		200			2400				10950	
F7 Katya		100		100		100							150	750					
F8 Angelina					150									350					
F9 Nadezhda		100				100			100		100			700					
F10 Rita		250												850					
	6500	6600	7900	4150	2000	2750	1700	1325	1600	1200	2150	3050	9650	84575	0	0	0	129000	

ROUTE 2 Stavropol area

CUSTOMER	21.09.2023	24.09.2023	28.09.2023	30.09.2023	03.10.2023	05.10.2023	08.10.2023	10.10.2023	13.10.2023	16.10.2023	20.10.2023	21.10.2023	23.10.2023	25.10.2023	27.10.2023	30.10.2023	31.10.2023	03.11.2023	05.11.2023
S (Stavropol)																			
S1 ILONA FLORA FANTASY	100	250	200		250			350			200			250		150	150	200	
S2 ANNA TSUM		100			100		100								100			100	
S3 SASHA PUSHKINSK RINOK		100	300		50		200										200		
S4 MISHA PUSHKINSKIY RINOK																			
S5 ALENA OK		50			100		100										100		
S6 LUDA 50 LET VLKSM	100				50		100		100	50									
S7 IRA TUHACHEVSKIY RINOK		200	200									50							
S8 SASHA TUCHACHEVKSIY RINOK		200	100		100				200		100	50			250		100		
S9 NATALIA PETROVNA TUHACHEVSK		150	100		200					100		150					50	50	
S10 NATALIA TUHACHEVSK RINOK													450				200		
S11 NATALIA TATARKA			100			100			100										
S12 SERGEI DARI CVETI			100		100							100					100		
S12 KATYA FLORA KONTORA			100				50			50				50			50		
S13 RAYA YUNOST			150					100									100		
S14 ANGELIKA CVETOCHNIE LUDI			50			50		50	50	50							50		
S15 ALENA FLOER			50		100	100	50	100	100	50	50							100	
S16 DMITRY ZAVODSKAYA TUHACH				900					1300		850				1500				2600
S17 ANATOLY MICHAILOVSK																			
S18 ARMEN SEROVA																			
S19 OLGA KOSMOS					200		100										200		
S20 NATALIA SALUT					100					50	50								
S21 REGINA					50													100	
S22 VIKA SOVREMENNIK					50			50											
S23 IRINA ROZALUX																			
S24 NASTYA RUMBA							100	50					200				100	100	
S25 TATIANA BELIY GOROD							150												
S26 KATYA ORANGE TUCHACHEVS									350	150									
S27 ALEXANDER PRO BUKET											150								
S28 KARINA PARTIZANSKAYA 3											150							200	
S29 TATIANA TUCHACH 26/5																	150		
S30 LERA KOMSOMOLSKAYA 65																	50		
S31 OLYA MAKOV CVET																	50		
S32 OLYA NIZ SEROVA																		50	
S33 YULIA SAVCHENKO ROGOZH																			
S34 KATYA TASHLA																		100	
S35 NADEZHDA OTRADNAYA/ROGOZH																			
S36 DENIS NATALIA STAV																			
TOTAL	200	1050	1450	900	1450	250	950	700	2200	500	1550	350	650	300	1850	150	1650	1000	2600

CUSTOMER	07.11.2023	10.11.2023	14.11.2023	17.11.2023	20.11.2023	21.11.2023	22.11.2023	24.11.2023	26.11.2023	27.11.2023	28.11.2023	01.12.2023	04.12.2023	05.12.2023	07.12.2023	12.12.2023	12.01.2023	16.01.2023	19.01.2023	21.01.2023	23.01.2023
S (Stavropol)																					
S1 ILONA FLORA FANTASY	200	50	100			450			1050	450		150		100	50	50		200	250	250	350
S2 ANNA TSUM								500													100
S3 SASHA PUSHKINSK RINOK									250		300	50		50							
S4 MISHA PUSHKINSKIY RINOK	100										200			150							
S5 ALENA OK						250															50
S6 LUDA 50 LET VLKSM						150															100
S7 IRA TUHACHEVSKIY RINOK				450				300				150									
S8 SASHA TUCHACHEVKSIY RINOK	400		150			1000					150	150	100			100					
S9 NATALIA PETROVNA TUHACHEVSK	200		200					200	100		200			200		200					
S10 NATALIA TUHACHEVSK RINOK		150					900			100											
S11 NATALIA TATARKA						100				100											
S12 SERGEI DARI CVETI								250	200						100		50				50
S12 KATYA FLORA KONTORA		50				250			50					50	50						50
S13 RAYA YUNOST	100																				
S14 ANGELIKA CVETOCHNIE LUDI		100				200					100	50									
S15 ALENA FLOER	200					400															50
S16 DMITRY ZAVODSKAYA TUHACH					6700			2200					400								
S17 ANATOLY MICHAILOVSK						2000															
S18 ARMEN SEROVA											1800										
S19 OLGA KOSMOS								100							100						
S20 NATALIA SALUT						150											150				
S21 REGINA		100				200				150				150		50	200				
S22 VIKA SOVREMENNIK						100			50						100		50				
S23 IRINA ROZALUX						300															
S24 NASTYA RUMBA	100					300		300			150			150			50		100		
S25 TATIANA BELIY GOROD				250							150							150			
S26 KATYA ORANGE TUCHACHEVS						1000															
S27 ALEXANDER PRO BUKET																					
S28 KARINA PARTIZANSKAYA 3				200		200											150				
S29 TATIANA TUCHACH 26/5																					
S30 LERA KOMSOMOLSKAYA 65	50		150					200													100
S31 OLYA MAKOV CVET	50		50			150		250								100					
S32 OLYA NIZ SEROVA																					
S33 YULIA SAVCHENKO ROGOZH																					
S34 KATYA TASHLA			50					100						100							
S35 NADEZHDA OTRADNAYA/ROGOZH			100					200									100			100	100
S36 DENIS NATALIA STAV																					
TOTAL	1400	450	800	900	6700	7200	900	4600	1700	800	3050	550	500	950	400	500	750	350	350	350	950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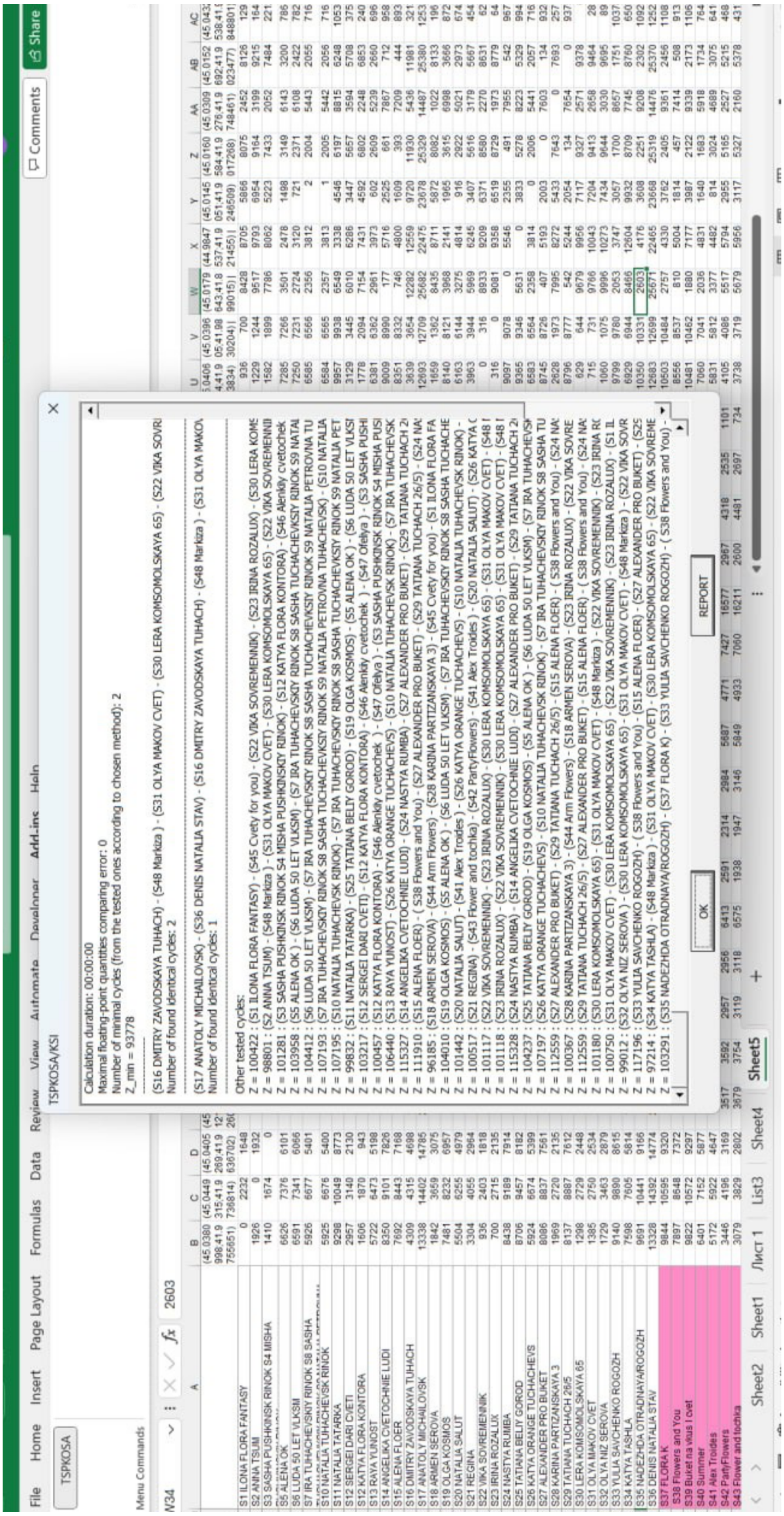
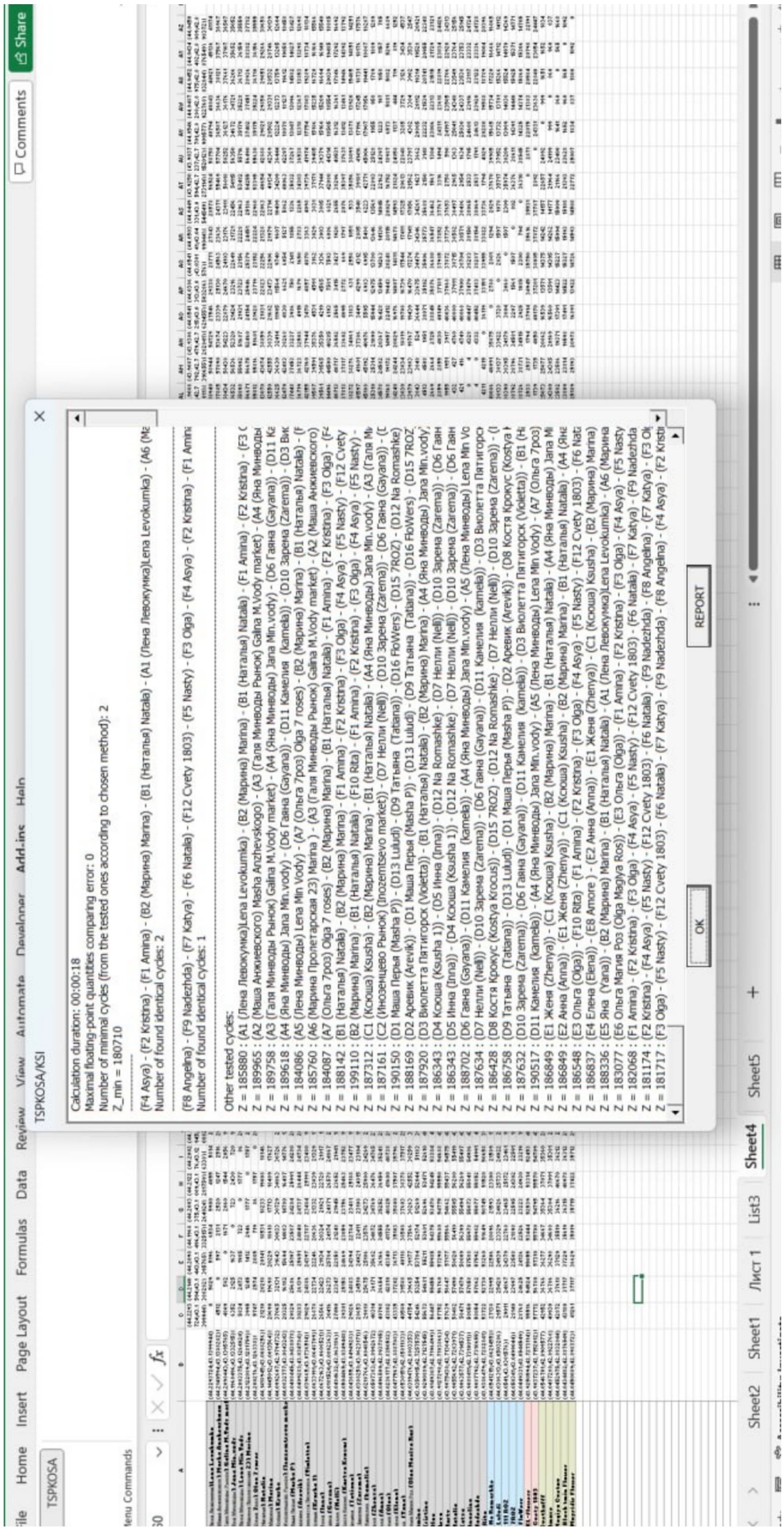
Calculation duration: 00:00:00
Maximal floating-point quantities comparing error: 0
Number of minimal cycles (from the tested ones according to chosen method): 1
Z_min = 178757
Number of found identical cycles: 1
Other tested cycles:
OK
REPORT
SAVINGSALGORITHM1
List1


TSPKOSA/KSI
Calculation duration: 00:00:00
Maximal floating-point quantities comparing error: 0
Number of minimal cycles (from the tested ones according to chosen method): 2
Z_min = 93778
Number of found identical cycles: 2
Number of found identical cycles: 1
Other tested cycles:
OK
REPORT
Sheet5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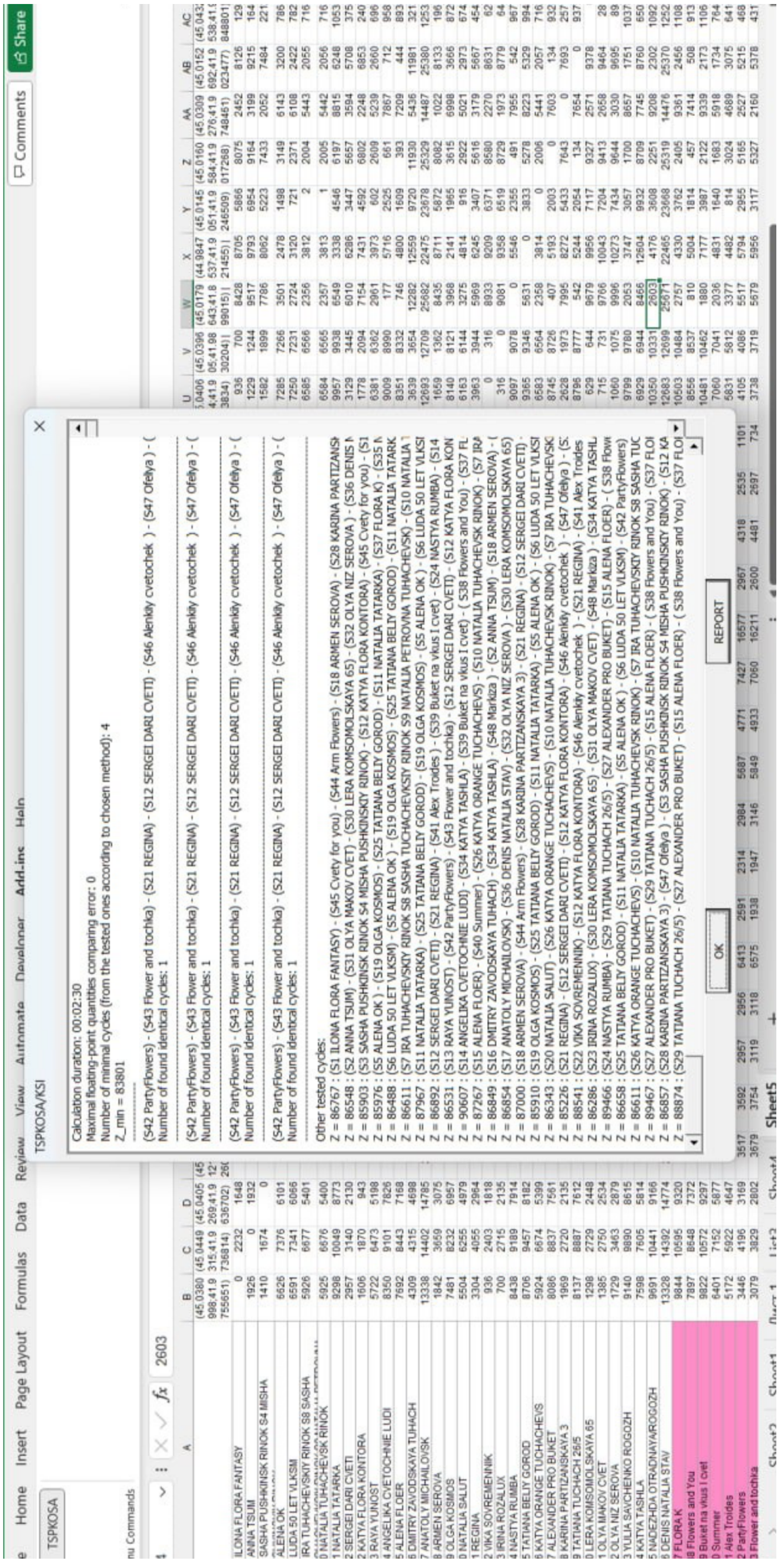
Calculation duration: 00:00:18
Maximal floating-point quantities comparing error: 0
Number of minimal cycles (from the tested ones according to chosen method): 2
Z_min = 180710
Number of found identical cycles: 2
Number of found identical cycles: 1
Other tested cycles:
OK
REPORT
Comments
Share
Sheet2
Sheet1
Лист 1
List3
Sheet4
Sheet5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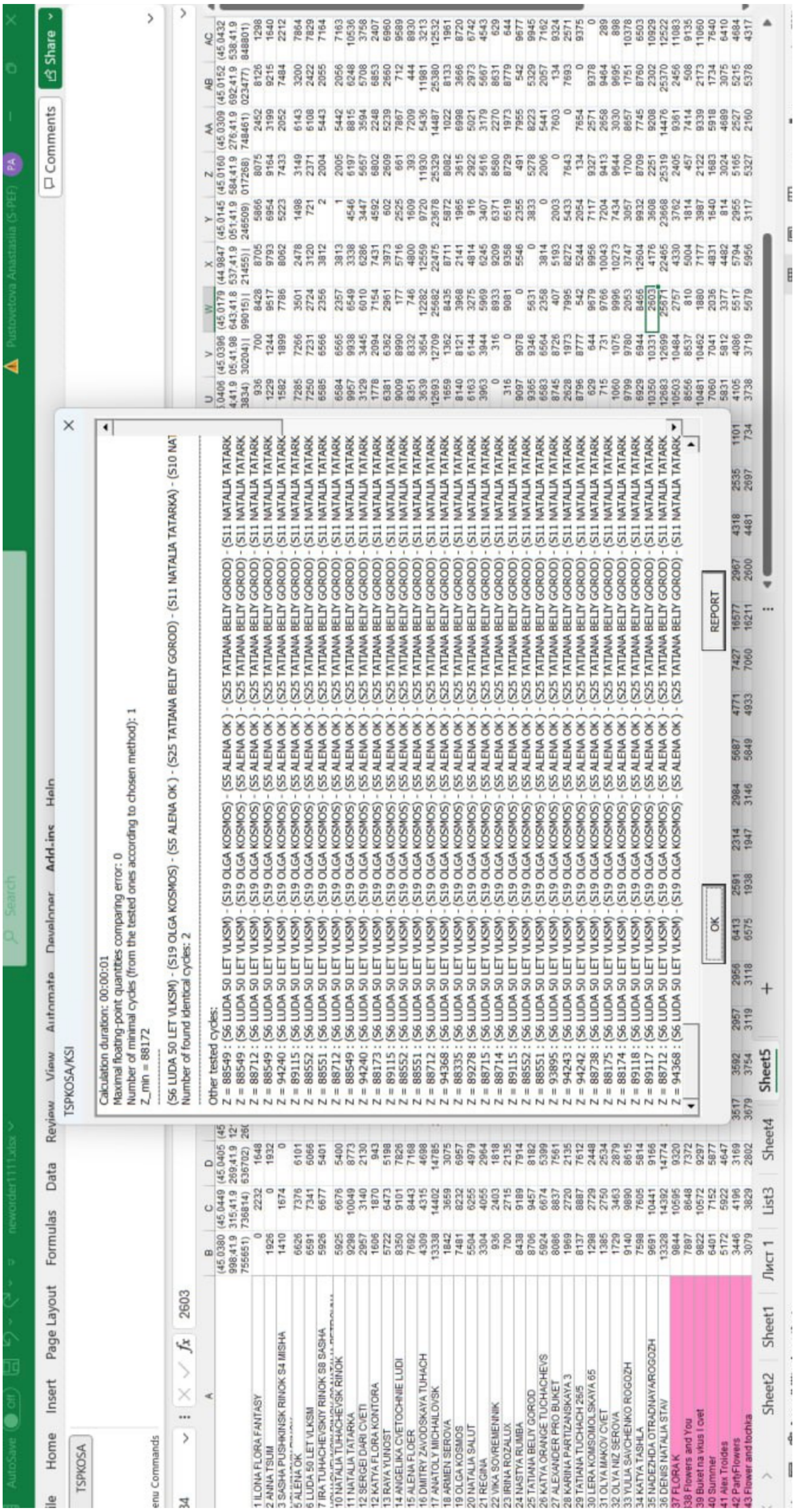
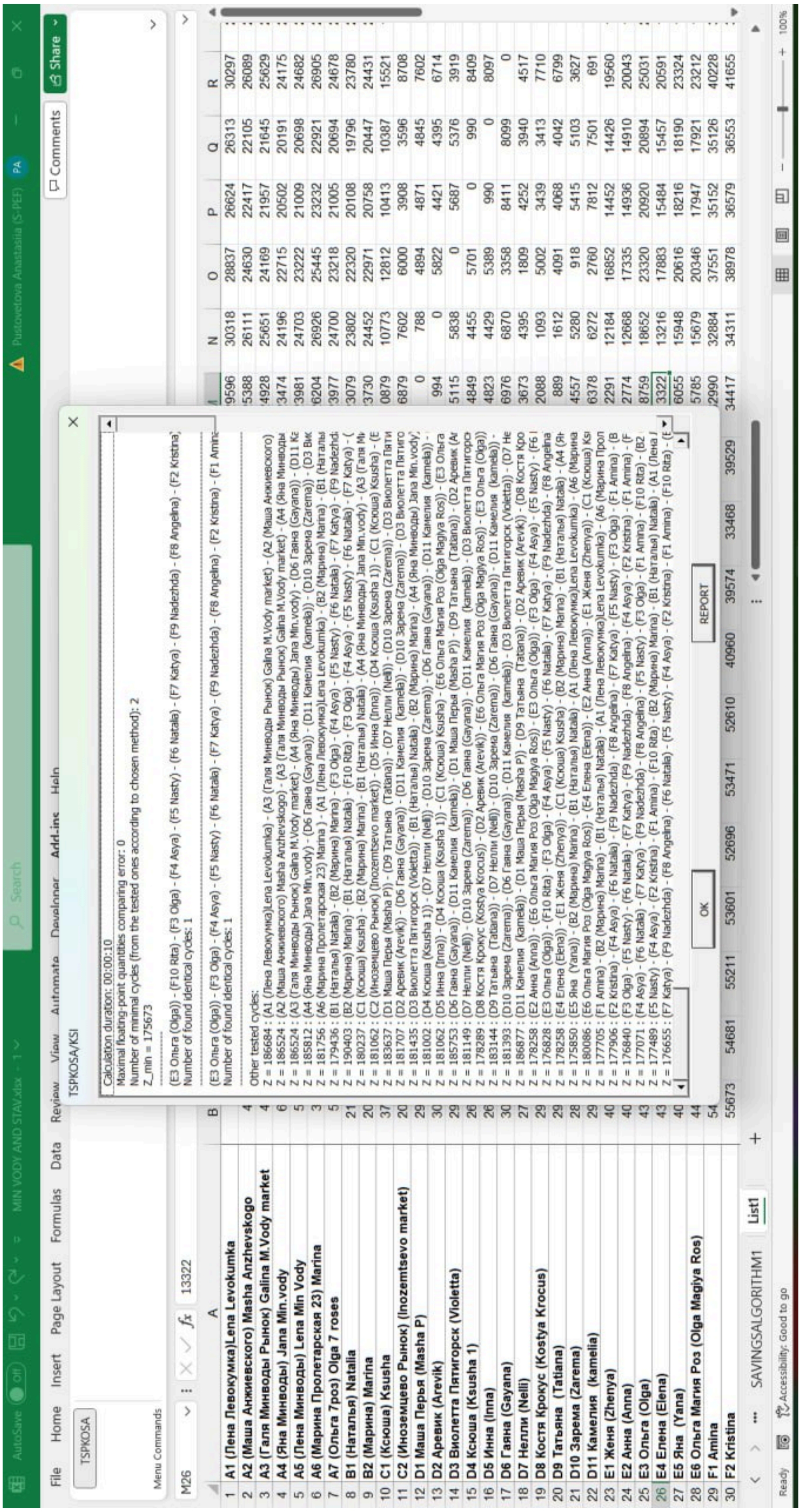
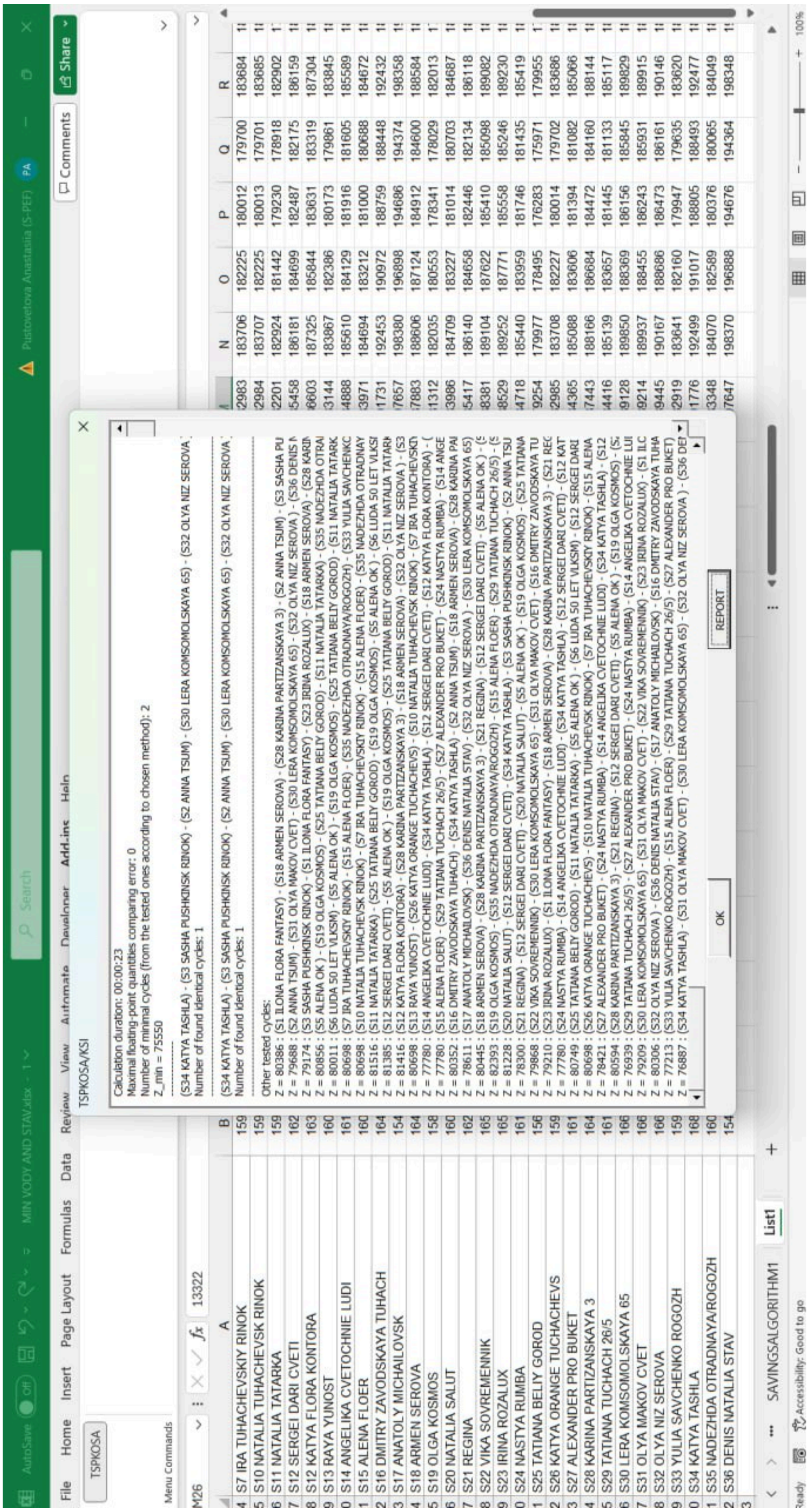
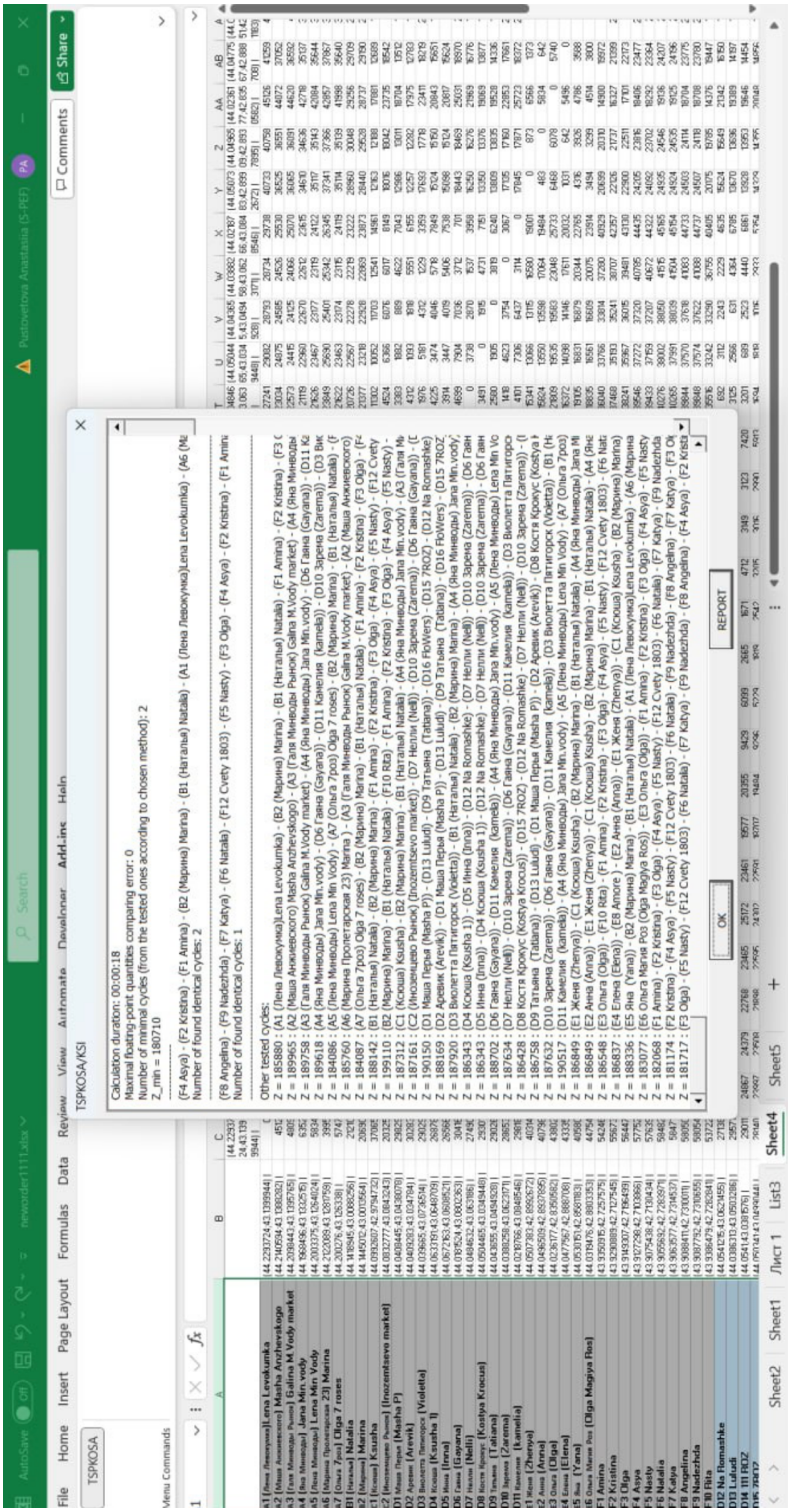
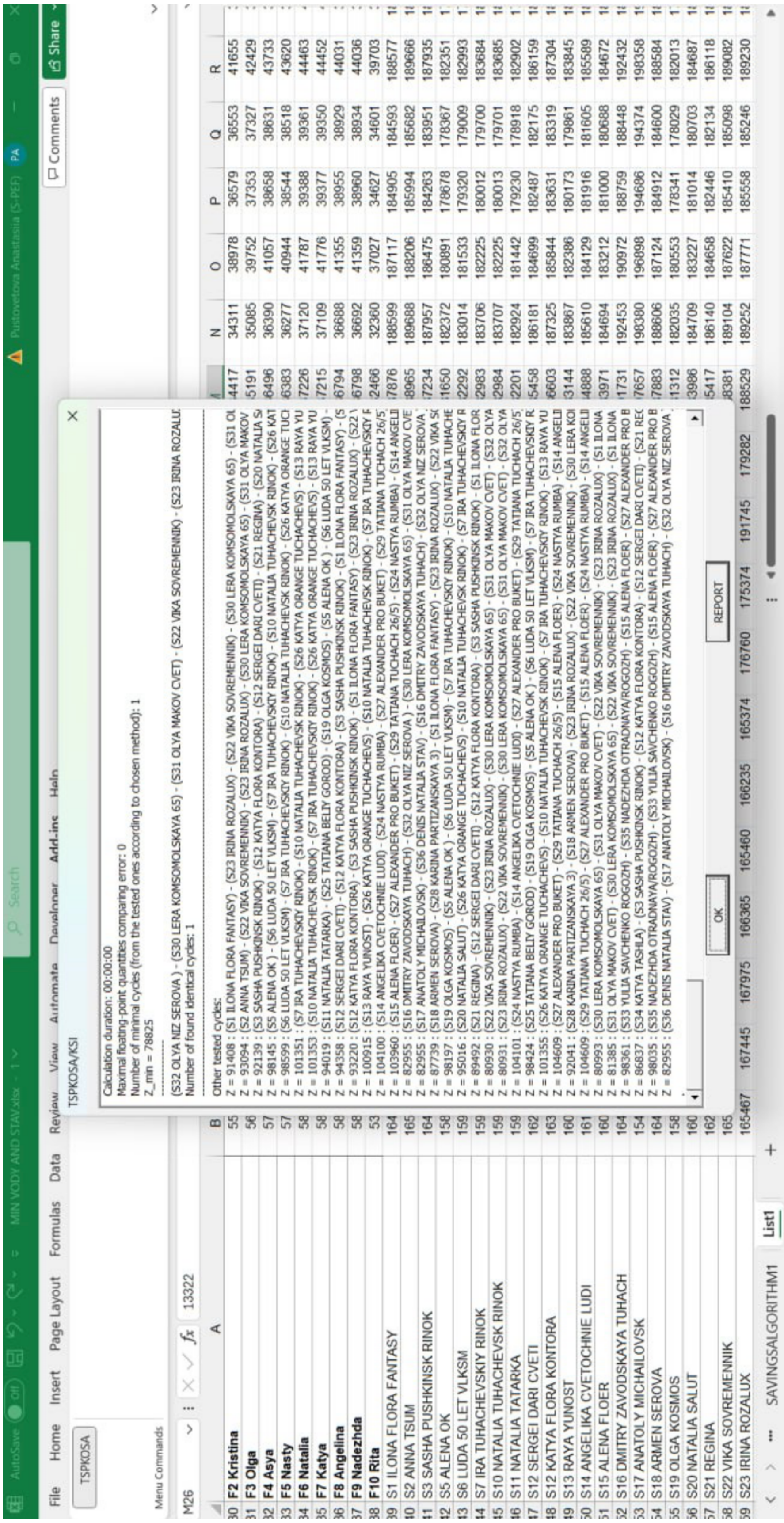
Calculation duration: 00:02:30
Maximal floating-point quantities comparing error: 0
Number of minimal cycles (from the tested ones according to chosen method): 4
Z_min = 83801
OK
REPORT


TSPKOSA/KSI
Calculation duration: 00:00:01
Maximal floating-point quantities comparing error: 0
Number of minimal cycles (from the tested ones according to chosen method): 1
Z_min = 88172
(S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARKA) - (S10 NAT
Number of found identical cycles: 2
Other tested cycles:
OK
REPORT


TSPKOSA/KSI
Calculation duration: 00:00:10
Maximal floating-point quantities comparing error: 0
Z_min = 175673
OK
REPORT
SAVINGSALGORITHM1
List1


File
Home
Insert
Page Layout
Formulas
Data
Review
View
Comments
Share
TSPKOSA
TSPKOSA/KSI
OK
REPORT
SAVINGSALGORITHM1
List1


TSPKOSA/KSI
Calculation duration: 00:00:18
Maximal floating-point quantities comparing error: 0
Z_min = 180710
Other tested cycles:
OK
REPORT
Sheet4
Sheet5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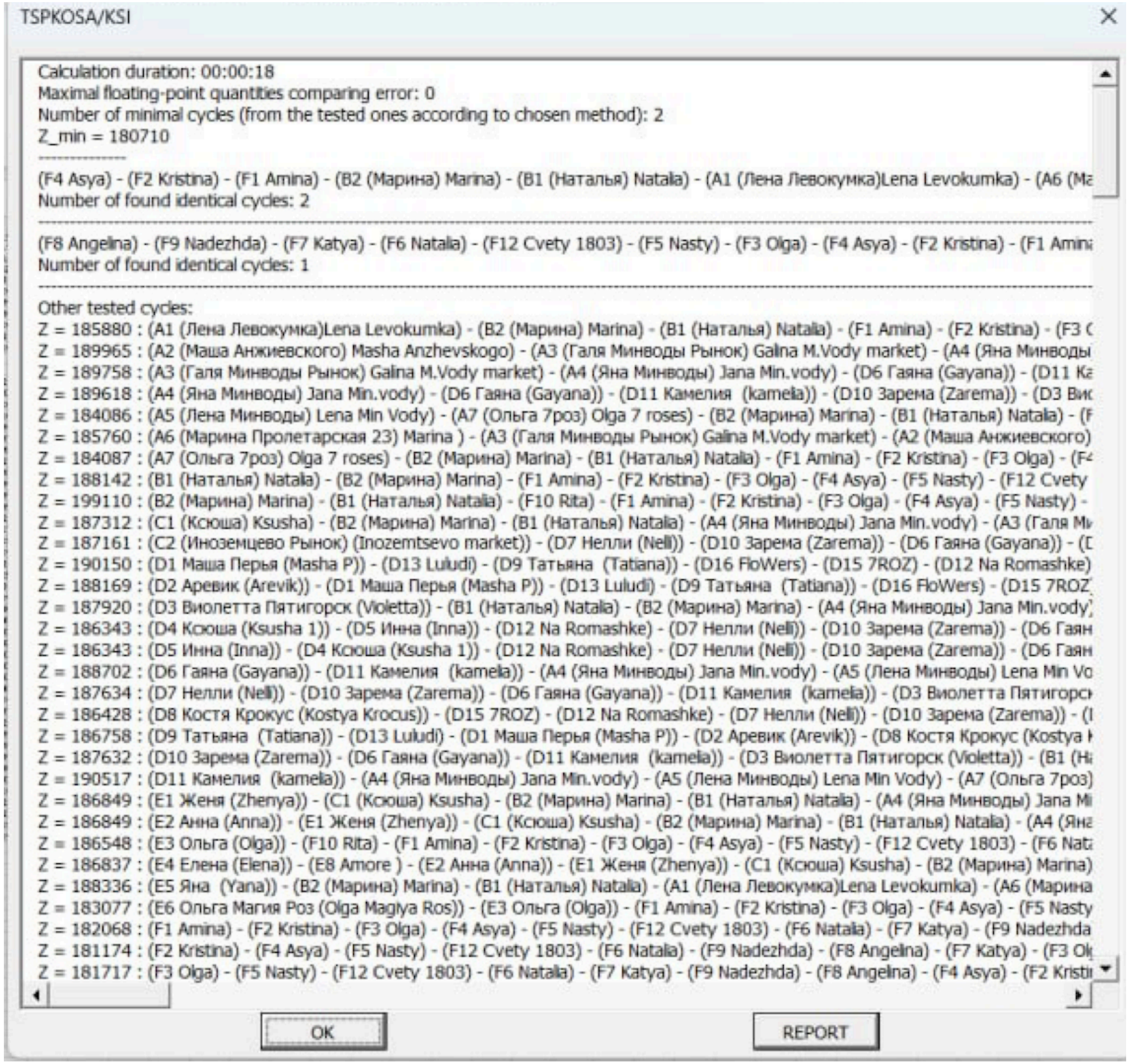
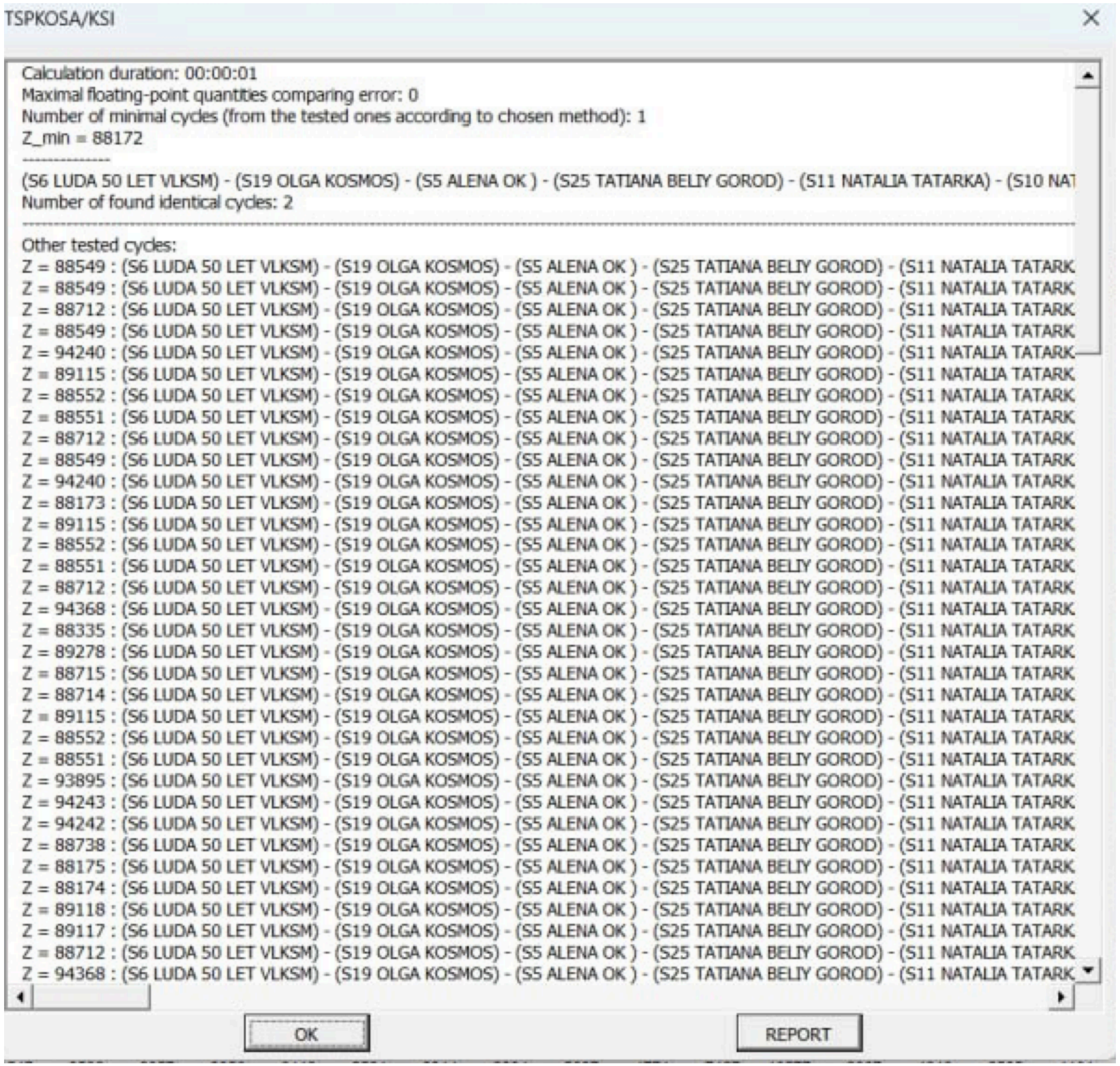
Maximal floating-point quantities comparing error: 0
Number of minimal cycles (from the tested ones according to chosen method): 1
Z_min = 78825
Number of found identical cycles: 1
Other tested cycles:
OK
REPORT
SAVINGSALGORITHM1
List1


TSPKOSA/KSI
Calculation duration: 00:00:18
Maximal floating-point quantities comparing error: 0
Number of minimal cycles (from the tested ones according to chosen method): 2
Z_min = 180710
(F4 Asya) - (F2 Kristina) - (F1 Amina) - (B2 (Марина) Marina) - (B1 (Наталья) Natalia) - (A1 (Лена Левокумка)Lena Levokumka)
Number of found identical cycles: 2
(F8 Angelina) - (F9 Nadezhda) - (F7 Katya) - (F6 Natalia) - (F12 Cvety 1803) - (F5 Nasty) - (F3 Olga) - (F4 Asya) - (F2 Kristina)
Number of found identical cycles: 1
Other tested cycles:
Z = 185880 : (A1 (Лена Левокумка)Lena Levokumka) - (B2 (Марина) Marina) - (B1 (Наталья) Natalia) - (F1 Amina) - (F2 Kristina)
Z = 189965 : (A2 (Маша Анжиевского) Masha Anzhevskogo) - (A3 (Галя Минводы Рынок) Galina M.Vody market)
Z = 189758 : (A3 (Галя Минводы Рынок) Galina M.Vody market) - (A4 (Яна Минводы) Jana Min.vody) - (D6 Гаяна (Gayana))
Z = 189618 : (A4 (Яна Минводы) Jana Min.vody) - (D6 Гаяна (Gayana)) - (D11 Камелия (kamelia)) - (D10 Зарема (Zarema))
Z = 184086 : (A5 (Лена Минводы) Lena Min Vody) - (A7 (Ольга 7роз) Olga 7 roses) - (B2 (Марина) Marina) - (B1 (Наталья) Natalia)
Z = 185760 : (A6 (Марина Пролетарская 23) Marina) - (A3 (Галя Минводы Рынок) Galina M.Vody market)
Z = 184087 : (A7 (Ольга 7роз) Olga 7 roses) - (B2 (Марина) Marina) - (B1 (Наталья) Natalia) - (F1 Amina) - (F2 Kristina) - (F3 Olga)
Z = 188142 : (B1 (Наталья) Natalia) - (B2 (Марина) Marina) - (F1 Amina) - (F2 Kristina) - (F3 Olga) - (F4 Asya) - (F5 Nasty)
Z = 199110 : (B2 (Марина) Marina) - (B1 (Наталья) Natalia) - (F10 Rita) - (F1 Amina) - (F2 Kristina) - (F3 Olga) - (F4 Asya) - (F5 Nasty)
Z = 187312 : (C1 (Ксюша) Ksusha) - (B2 (Марина) Marina) - (B1 (Наталья) Natalia) - (A4 (Яна Минводы) Jana Min.vody)
Z = 187161 : (C2 (Иноземцево Рынок) (Inozemtsevo market)) - (D7 Нелли (Nelli)) - (D10 Зарема (Zarema)) - (D6 Гаяна (Gayana))
Z = 190150 : (D1 Маша Перья (Masha P)) - (D13 Luludi) - (D9 Татьяна (Tatiana)) - (D16 FloWers) - (D15 7ROZ) - (D12 Na Romashke)
Z = 188169 : (D2 Аревик (Arevik)) - (D1 Маша Перья (Masha P)) - (D13 Luludi) - (D9 Татьяна (Tatiana)) - (D16 FloWers)
Z = 187920 : (D3 Виолетта Пятигорск (Violetta)) - (B1 (Наталья) Natalia) - (B2 (Марина) Marina) - (A4 (Яна Минводы) Jana Min.vody)
Z = 186343 : (D4 Ксюша (Ksusha 1)) - (D5 Инна (Inna)) - (D12 Na Romashke) - (D7 Нелли (Nelli)) - (D10 Зарема (Zarema))
Z = 186343 : (D5 Инна (Inna)) - (D4 Ксюша (Ksusha 1)) - (D12 Na Romashke) - (D7 Нелли (Nelli)) - (D10 Зарема (Zarema))
Z = 188702 : (D6 Гаяна (Gayana)) - (D11 Камелия (kamelia)) - (A4 (Яна Минводы) Jana Min.vody)
Z = 187634 : (D7 Нелли (Nelli)) - (D10 Зарема (Zarema)) - (D6 Гаяна (Gayana)) - (D11 Камелия (kamelia))
Z = 186428 : (D8 Костя Крокус (Kostya Krocus)) - (D15 7ROZ) - (D12 Na Romashke) - (D7 Нелли (Nelli)) - (D10 Зарема (Zarema))
Z = 186758 : (D9 Татьяна (Tatiana)) - (D13 Luludi) - (D1 Маша Перья (Masha P)) - (D2 Аревик (Arevik))
Z = 187632 : (D10 Зарема (Zarema)) - (D6 Гаяна (Gayana)) - (D11 Камелия (kamelia)) - (D3 Виолетта Пятигорск (Violetta))
Z = 190517 : (D11 Камелия (kamelia)) - (A4 (Яна Минводы) Jana Min.vody) - (A5 (Лена Минводы) Lena Min Vody)
Z = 186849 : (E1 Женя (Zhenya)) - (C1 (Ксюша) Ksusha) - (B2 (Марина) Marina) - (B1 (Наталья) Natalia)
Z = 186849 : (E2 Анна (Anna)) - (E1 Женя (Zhenya)) - (C1 (Ксюша) Ksusha) - (B2 (Марина) Marina) - (B1 (Наталья) Natalia)
Z = 186548 : (E3 Ольга (Olga)) - (F10 Rita) - (F1 Amina) - (F2 Kristina) - (F3 Olga) - (F4 Asya) - (F5 Nasty) - (F12 Cvety 1803)
Z = 186837 : (E4 Елена (Elena)) - (E8 Amore) - (E2 Анна (Anna)) - (E1 Женя (Zhenya)) - (C1 (Ксюша) Ksusha) - (B2 (Марина) Marina)
Z = 188336 : (E5 Яна (Yana)) - (B2 (Марина) Marina) - (B1 (Наталья) Natalia) - (A1 (Лена Левокумка)Lena Levokumka)
Z = 183077 : (E6 Ольга Магия Роз (Olga Magiya Ros)) - (E3 Ольга (Olga)) - (F1 Amina) - (F2 Kristina) - (F3 Olga) - (F4 Asya)
Z = 182068 : (F1 Amina) - (F2 Kristina) - (F3 Olga) - (F4 Asya) - (F5 Nasty) - (F12 Cvety 1803) - (F6 Natalia) - (F7 Katya)
Z = 181174 : (F2 Kristina) - (F4 Asya) - (F5 Nasty) - (F12 Cvety 1803) - (F6 Natalia) - (F9 Nadezhda) - (F8 Angelina) - (F7 Katya)
Z = 181717 : (F3 Olga) - (F5 Nasty) - (F12 Cvety 1803) - (F6 Natalia) - (F7 Katya) - (F9 Nadezhda) - (F8 Angelina) - (F4 Asya)
OK
REPORT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Number of minimal cycles (from the tested ones according to chosen method): 1
Z_min = 88172

(S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARKA) - (S10 NAT
Number of found identical cycles: 2
Other tested cycles:
Z = 88549 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 88549 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 88712 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 88549 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 94240 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 89115 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 88552 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 88551 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 88712 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 88549 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 94240 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 88173 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 89115 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 88552 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 88551 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 88712 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 94368 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 88335 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 89278 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 88715 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 88714 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 89115 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
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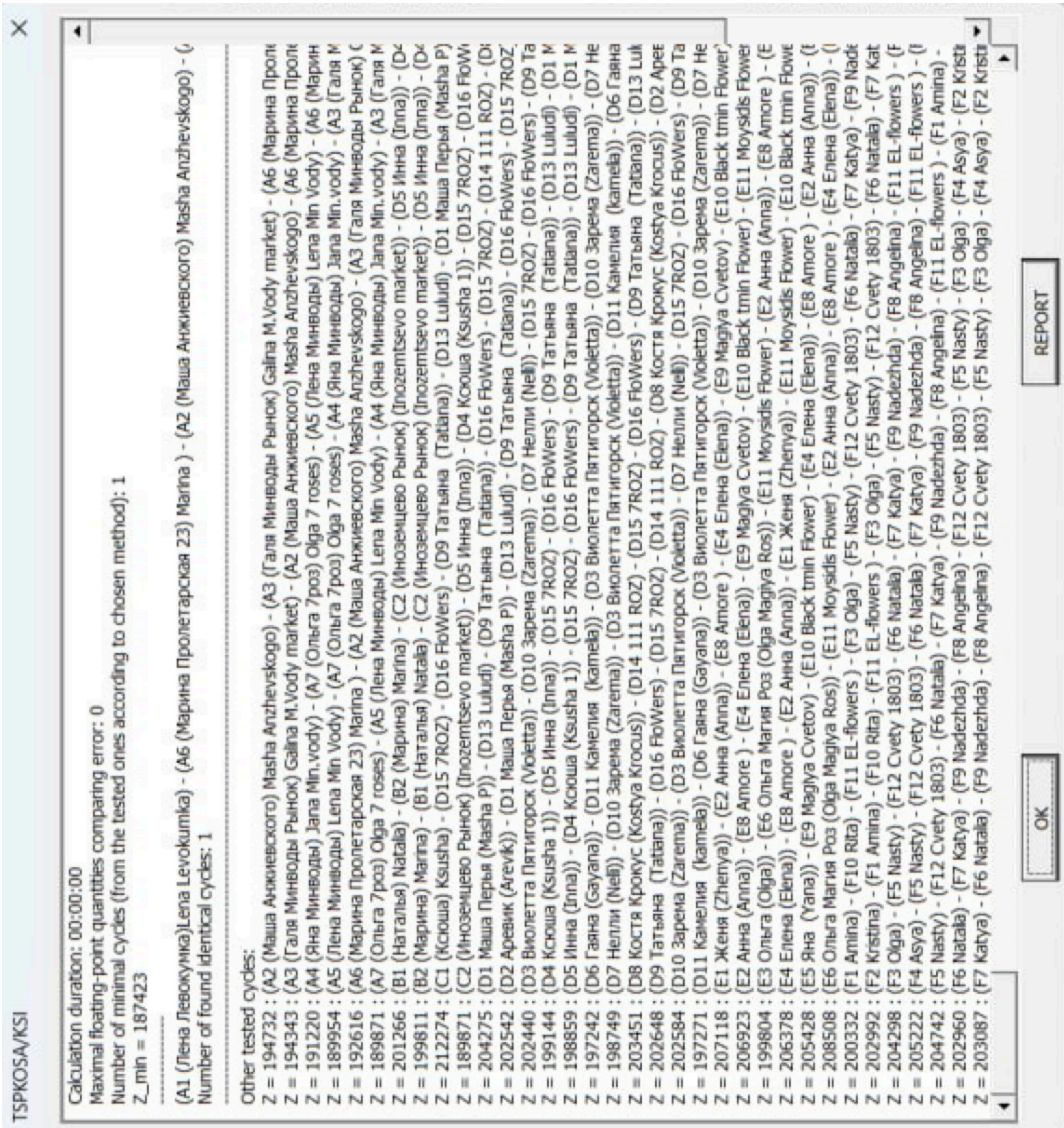
Z = 93895 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 94243 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 94242 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 88738 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 88175 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 88174 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 89118 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 89117 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 88712 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
Z = 94368 : (S6 LUDA 50 LET VLKSM) - (S19 OLGA KOSMOS) - (S5 ALENA OK) - (S25 TATIANA BELIY GOROD) - (S11 NATALIA TATARK
OK
REPORT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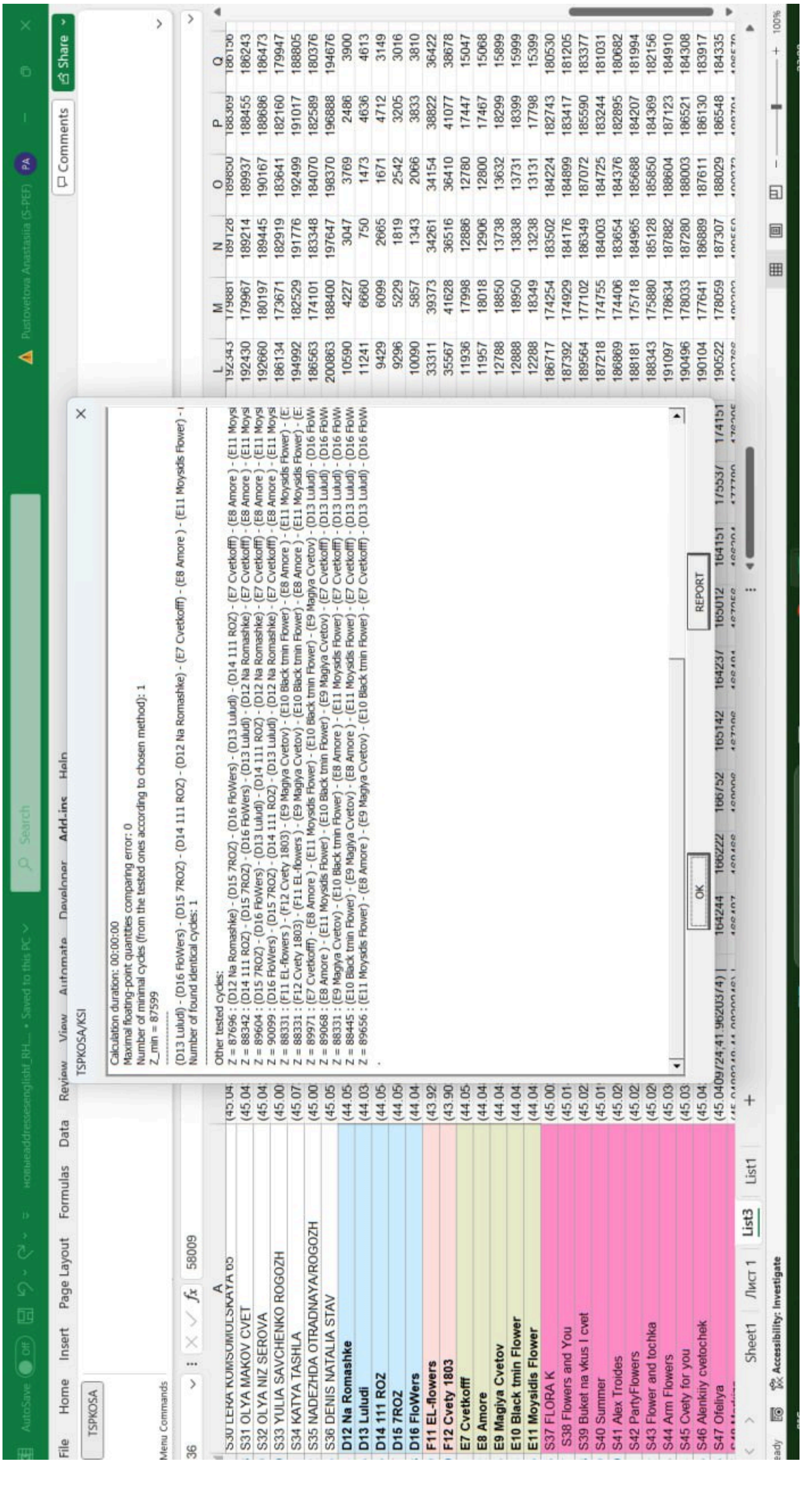
Z_min = 187423
Number of found identical cycles: 1
Other tested cycles:
OK
REPORT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Calculation duration: 00:00:00
Maximal floating-point quantities comparing error: 0
Number of minimal cycles (from the tested ones according to chosen method): 1
Z_min = 87599
(D13 Luludi) - (D16 FloWers) - (D15 7ROZ) - (D14 111 ROZ) - (D12 Na Romashke) - (E7 Cvetkoff) - (E8 Amore) - (E11 Moysidis Flower) -
Number of found identical cycles: 1
Other tested cycles:
OK
REPORT

A1	44.22937239031017,43.13999439557137	1
A2	44.21405944287147,43.13882823903143	2
A3	44.20984431039009,43.13957649371636	3
A4	44.19684964825135,43.133251480224104	4
A5	44.200337543902464,43.12640235324189	5
A6	44.212208871733125,43.12817588022525	6
A7	44.200276011293, 43.12633798022445	7
B1	44.14189445759665, 43.00882563789279	8
B2	44.14450124956893, 43.00135642440175	9
C1	44.099260656853, 42.979473197415956	10
C2	44.083277655626325,43.08432432335263	11
D1	44.04084446811204, 43.04380778392053	12
D2	44.04092830597797, 43.03478396486833	13
D3	44.03966497149804, 43.07365142624798	14
D4	44.063319069045875,43.06487091645373	15
D5	44.01815242365114, 43.08023628206534	16
D6	44.04846318734036, 43.06318596857615	17
D7	44.0504464711567, 43.03494476486904	18
D8	44.04365497135362, 43.04949281090326	19
D9	44.038825798533004,43.06231708206677	20
D10	44.0218765530911, 43.08485462253944	21
E1	44.0507383040735, 42.89926716857638	22
E2	44.04965089563931, 42.89378945137761	23
E3	44.023617719538194,42.835058197410596	24
E4	44.047756703968034, 42.88870799555863	25
E5	44.05301514368957, 42.85811830905034	26
E6	44.03194764172968, 42.88033532254012	27
F1	43.93509151977095, 42.7257574667146	28
F2	43.92908887074918, 42.71275453787792	29
F3	43.91493073099729, 42.719649853221796	30
F4	43.91272982268825, 42.710386639730494	31
F5	43.90754375434915, 42.713043437876394	32

F6	43.90556920029966, 42.728397126238676	33
F7	43.90635769949821, 42.73145369554879	34
F8	43.90884105734651, 42.731001080204045	35
F10	43.93864786414017, 42.72828413787864	36

S1	45.03809980604509,41.97556513795609	1
S2	45.044931505446606,41.97368136864643	2
S3	45.040526898005304,41.96367015330119	3
S4	45.00521208581309,41.926015237953735	4
S5	45.008704729926166,41.922985939807695	5
S6	45.01448990795566, 41.924629453299346	6
S7	44.98502086685845, 41.94963805329726	7
S8	45.036477987137445, 41.94159415330088	8
S9	45.03853391819497, 41.958017264938654	9
S10	45.013008911289965, 41.92755708028186	10
S11	45.01822349326278, 41.896819733989545	11
S12	45.01557254307586, 41.90633201097186	12
S13	45.05283204214861, 42.00659896679336	13
S14	45.05764241424821, 42.129658739811155	14
S15	45.03026422671235, 41.98424728213676	15
S16	44.99881721645255, 41.922882326315694	16
S17	45.019338400388804, 41.92482498028231	17
S18	45.030890906308684, 41.95136886679179	18
S19	45.04068943001435, 41.98038337843008	19
S20	45.03960503863731, 41.983020364938696	20
S21	45.0179643160626, 41.89901498028216	21
S22	44.98475367488968, 41.92145495329728	22
S23	45.01450507698115, 41.924650910971806	23

S24	45.03092758858772, 41.97484609377442	24
S25	45.01526924391945, 41.90234772446314	25
S26	45.04325384317722, 41.98488008028394	26
S27	45.04363531964678, 41.986683080284	27
S28	45.04225916883432, 41.99364058399121	28
S29	45.00507974336443, 41.901531680281245	29
S30	45.07364150478916, 41.93495792446734	30
S31	45.00335249313699, 41.89956543795364	31
S32	45.05774342574175, 42.129722668647375	32

Identifier per city	Coordinates on the map
D12	44.05412151596161, 43.06214552368141
D13	44.038631275118306,43.05032863558516
D14	44.05409996273304, 43.03815759669633
D15	44.05034104925362, 43.04990439669606
D16	44.044933072366725,43.05445485251676
F11	43.92505940994062, 42.72731138134585
F12	43.903723700575036,42.71520119320682
E7	44.054670050815595,42.89095772553212
E8	44.048728775321, 42.8922768101886
E9	44.04529745419276, 42.88328436786002
E10	44.043448223828406,42.88765488135242
E11	44.04500888403824, 42.89837202553157
S37	45.002629232262414,41.90087394943866
S38	45.01471774544687,41.905337567913634

S39	45.02215759068428, 41.89233579674979
S40	45.01973624764887, 41.91514395257065
S41	45.02004847922859, 41.92752603907808
S42	45.022451607416194,41.953353681406526
S43	45.02627133033611, 41.95174912558593
S44	45.03018840241277, 41.984247283257744
S45	45.03544402427447, 41.969920996750666
S46	45.042066837419156, 41.95516700527455
S47	45.04097239652316, 41.96203741024352
S48	45.048834790488335, 41.9839245814081