Czech University of Life Sciences Prague

Faculty of Economics and Management

Department of Systems Engineering (FEM)

Bachelor Thesis

Designing the Optimal Transportation for Mobicom Corporation in Mongolia

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Thesis title

Designing the Optimal Transportation for Mobicom Corporation in Mongolia

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Objectives of thesis

The goal of the thesis is to determine an optimal arrangment of the chosen transportation routes for the mongolian company Mobicom. The company supplies electric products and networks around Mongolia.

Methodology

The theoretical part will describe the related methods needed for transport optimization and will be based on the relevant monographies and scientific papers. applied theories. And the representation of the data I have.

In the practical part, suitable methods will be chosen to find an efficient transportation solution. The methods will respect the distance and time travelled in order to minimize the transportation costs. In the same time, the quality of the routes will have to be considered. The different scenarios will be investigated and the discussion will provide a viewpoint how realistic these solutions are in the practical and economical sense.

The proposed extent of the thesis

40

Keywords

logistics, optimization, transportation.

Recommended information sources

A Closer Look at the Travelling Salesman Problem, edited by Christina V. Østergaard, Nova Science Publishers, Incorporated, 2020. ProQuest Ebook Central, https://ebookcentral-proquest-com.infozdroje.czu.cz/lib/czup/detail.action?docID=6173751.

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CHONG, Edwin Kah Pin; ŻAK, Stanislaw H. *An introduction to optimization.* Hoboken, New Jersey: Wiley, 2013. ISBN 9781118279014.

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Prague on 15. 03. 2024

Declaration

I declare that I have worked on my bachelor thesis titled "Designing the Optimal Transportation for Mobicom Corporation in Mongolia" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the bachelor thesis, I declare that the thesis does not break any copyrights.

In Prague on 15th of March, 2024 ______________________________

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In the end, I want to thank my parents with all my heart. In times of the lowest and highest moments in my life, they have been always there to support me.

Designing the Optimal Transportation for Mobicom Corporation in Mongolia

Abstract

The goal of the thesis is to determine an optimal arrangment of the chosen transportation routes for the mongolian company Mobicom. The company supplies electric products and networks around Mongolia.

The theoretical part will describe the related methods needed for transport optimization and will be based on the relevant monographies and scientific papers. applied theories. And the representation of the data I have.

In the practical part, suitable methods will be chosen to find an efficient transportation solution. The methods will respect the distance and time travelled in order to minimize the transportation costs. In the same time, the quality of the routes will have to be considered. The different scenarios will be investigated and the discussion will provide a viewpoint how realistic these solutions are in the practical and economical sense.

Keywords: logistics, optimization, transportation.

Návrh optimální dopravy pro společnost Mobicom v Mongolsku

Abstrakt

Cílem této práce je určit optimální uspořádání vybraných dopravních tras pro mongolskou společnost Mobicom, která dodává elektrické produkty a sítě po celém Mongolsku.

Teoretická část bude popisovat související metody potřebné pro optimalizaci dopravy a bude se opírat o relevantní monografie a vědecké práce. Aplikované teorie a reprezentaci dostupných dat.

V praktické části budou vybrány vhodné metody pro nalezení efektivního dopravního řešení. Tyto metody budou zohledňovat vzdálenost a čas cestování za účelem minimalizace nákladů na dopravu. Zároveň bude nutné zohlednit kvalitu tras. Různé scénáře budou zkoumány a diskuse poskytne pohled na to, nakolik jsou tyto řešení reálná z praktického a ekonomického hlediska.

Klíčová slova: logistika, optimalizace, doprava

Table of content

1 Introduction

Throughout all the ages of history, man has wanted to figure out how to reach maximum efficiency and profit by keeping utility usage at the minimum point. Once upon a time, the Silk Road was the greatest exchange road that connected the Eastern and Western worlds. All the Infrastructure and safety were once settled and guarded by the Mongols until the 14th century. All the means are intercepts at one point. Most Efficiency Gain and Least Utility Usage.

The situation in the Corporation in Mongolia called Mobicom is one of the shattered mirror images that has a similar problem that broaches to our subject. Mobicom Corporation is the biggest network company in Mongolia. Just like any other network company Mobicom is facing some transporting problems with their goods and services. Even nowadays they are not certain about the optimal route and balancing.

By doing research and calculating the road lengths and possible variations. There is a very high chance that I can find an even more optimal way of transportation. It would be very influential to Mongolia; on the other hand, it is my home country. Mongolia is a small country in terms of population and economy. Having bigger and stronger corporations is the most suitable bridge to become a wealthier country. I have the idea that" If the individuals are wealthy then the country will bloom with wealth."

In this thesis, I would generally apply mathematical modeling methods to solve the detailed problems. I believe that, with mathematical presence and logical reasoning society could find the solutions.

Mongolia is separated into 29 cities and 21 provinces; it is ranked as the 18th largest country in the world with only 3.5 million people. All the transportation starts from the capital Ulaanbaatar. There are 7 main roads that lead to other parts of the country.

2 Objectives and Methodology

2.1 Objectives

In this research, I will try to evaluate the variations that could be optimal for the crossing distance. To do that comparing is the clear way to get to my objective. Unfortunately, comparing is the easiest part and also the last step. To compare there must at least dozens of solutions to brainstorm on. I will assess the existing transportation infrastructure, routes, and logistics processes employed by Mobicom Corporation in Mongolia.

2.2 Methodology

This bachelor's thesis consists of few core parts.

- First part, part that will present theoretical background.

In this section, the thesis will more focus on the theory of mathematics and its algorithms. Especially in Graph Theory. Because the transportation problem itself was always been an analogy of Graph Theory in Real Life. Famous algorithms and their background are deeply connected with this logistic problem. Interesting ideas and cases will be shown in this section. Will analyze what is Logistics and what are the properties of it. The introduction of variables that must be considered in the optimal transportation routes will take place. Challenges of convenience of the solution will be considered.

- The second part will be the presenting part which will show all the calculations.

This part will present the calculations and their logic. Dijkstra's algorithm and The Nearest Neighbor, Lin Kernighan's heuristic algorithm and Excel Solver's methods will also consist to gain the solution. Logical Constraints will arguably include. Distances between cities will be put into a matrix. Matrix that will help to evaluate and do the calculations. Cases will be different, depending on the resource we will assume that we have. Presentation of the graphs that shows the vertices and nodes, and the table that shows the distances between those nodes will be included. it may support the future works that has similar basis.

I will also calculate the financial variables such as cost, expenses of my Scoping corporation (Mobicom) based on the results from my TSP optimization. The economic conditions of Mongolia is very different during the warm and cold seasons it will also guide us into 2 different calculations.

3 Literature Review

3.1 Optimization

Optimization is central to any problem involving decision making, whether in engineering or in economics. The task of decision making entails choosing among various alternatives. This choice is governed by our desire to make the "best" decision. The measure of goodness of the alternatives is described by an objective function or performance index. Optimization theory and methods deal with selecting the best alternative in the sense of the given objective function (17).

3.2 Shortest Path and Creating the Optimal Touring Loop

The Shortest Path is a problem finding or find the shortest path between a point or what is called a vertex in a graph that has a number of values on the edge graph or a path that connects the points with the smallest value. There are several steps needed to find the shortest path including:

• Creates a table of distances between vertices / edges and gives the value of each of these edges, the previous vertex, the visited vertex, and the current visited vertex.

• The initial vertices are assigned a value of 0 as a starting point.

• Vertices that have been visited must be marked and cannot be visited again.

• Performs value calculations and updates the distance as well as the previous vertex list based on the vertex to be visited from the current vertex.

• Repeat the process that was done in the third step and so on until all the vertices have been visited (13).

These methods are based on nonparametric density estimation algorithms which have been developed since the early 1950s.

$$\int (x) = \sum_{i=1}^{n} k(x, x_i) / n$$ [1]

k is the kernel's coefficient that indicates it is measuring the distance between vertex x and vertex x_i , sum of the distances between the main vertex and the remaining vertices and dividing It to the total vertex number n to get the average.

The kernel methods estimate densities based on the sum of a set of functions where k must satisfy certain regularity conditions (4).

Dijkstra's algorithm is one of the most suitable for finding the shortest path in this case, due to the weighted vertices. We use Dijkstra's Algorithm to find the most efficient and optimal route in terms of distance and time. Geographically located places and the distances between those places are always positive rational numbers. This leads to creating matrices and applying Dijkstra's algorithm.

3.3 TSP /Travelling Salesman Problem/

The traveling salesman problem (TSP) has been recorded in the history of combinatorial optimization since 1930. Merrill M. Flood first provided a mathematical formulation of the problem when he came across it while solving a school bus routing problem (Flood, 1948). Given a set of cities, the TSP looks for the least-cost tour that visits all of the cities. It can be modeled as an undirected graph whose vertices are the cities and the edges are the paths between the cities. The TSP is one of the most investigated problems in optimization, being used as a benchmark for several optimization techniques. There exist several aspects which justify the popularity and relevance of the TSP. Although the problem is computationally difficult there are various efficient exact or heuristic algorithms that make it solvable when dealing with large-size graphs with up to millions of nodes (7).
TSP is the root of the graph problems that we can observe in the real world. Mathematicians and statisticians cannot be absolute about the solutions that came out of the various algorithms but we, humans have to make decisions, otherwise we won't move on from the zugzwang (as the people say in chess, the hard position where you don't see the good decision to make).
The traveling salesman problem (TSP) is to find a routing of a salesman who starts from a home location, visits a prescribed set of cities and returns to the original location in such a way that the total distance travelled is minimum and each city is visited exactly once. Although a business tour of a modern-day traveling salesman may not seem to be too complex in terms of route planning, the TSP in its generality represents a typical 'hard' combinatorial optimization problem. TSP was known among mathematicians and statisticians under various names. Karl Menger considered a variation of TSP called the messenger problem . It may be noted that the messenger problem and TSP are equivalent

in the sense that one problem can be reduced to the other using very simple transformations. Bock gives an English translation of the description of messenger problem from as follows: "We designate as the Messenger Problem (since this problem is encountered by every postal messenger, as well as by many travelers) the task of finding, for a finite number of points whose pairwise distances are known, the shortest path connecting the points. This problem is naturally always solvable by making a finite number of trials below the number of permutations of the given points. The rule, that one should first go from the starting point to the nearest point, then to the point nearest to this etc., does not in general result in the shortest path (6)."

3.3.1 Heuristic Algorithms

A heuristic is an approximation method that provides a satisfactory solution by limiting exploration of feasible solutions. The word heuristic is derived from the Greek word "heuriskein" which means art of discovering new strategies to solve problems (11).
Terms such as algorithms and heuristics is like two sides of a coin. The algorithm is more instructive and dictated by the rules to obtain a solution while the Heuristic is more similar to strategy to gain a solution. The moving path of the Algorithm is rules on the other hand Heuristic follows intuition and the logic of the researcher. However, by saying Heuristic Algorithm I might sound weird. But in TSP, the main players are Heuristic Algorithms. Heuristic Algorithms have strict rules that must be obeyed by the researchers but also contain experience and intuition-based iterations.
Before designing a heuristic method to find good solutions to a problem, it is necessary to be able to formalize it mathematically and to check that it belongs to a difficult class. Thus, this chapter recalls some elements and definitions in graph theory and complexity theory in order to make the book self-contained. On the one hand, basic algorithmic courses very often include graph algorithms. Some of these algorithms have simply been transposed to solve difficult optimization problems in a heuristic way. On the other hand, it is important to be able to determine whether a problem falls into the category of difficult problems. Indeed, one will not develop a heuristic algorithm if there is an efficient algorithm to find an exact solution (16).

3.3.2 Nearest Neighbor Method

By applying the characteristics of the Nearest Neighbor Method, we will obtain the most natural solution.

The nearest neighbor rule is arguably the simplest and most intuitively appealing nonparametric classification procedure. However, relatively little is known about the manner in which this method is influenced by the value of k, or about properties of empirical selectors for k. We shall discuss these and related issues (12).

3.3.3 Dijkstra's Algorithm

3.3.3.1 Traditional Dijkstra's Algorithm

Dijkstra's algorithm is not directly connected with the TSP, however, there are some ways. For an example, converting the TSP into a graph problem is a way. By creating the circular model graph. Throughout the history of mathematics, there was this Hamiltonian cycle was proposed by many mathematicians.
Let's say:

$$G = (V, E) \qquad [2]$$

is a weighted graph, in real-life practice distances are positive rational units. In this case "V" is set of vertices which are the locations in real life.
"E" is set of edges which are the roads that connect the places.

There are also elements and rules that we must adopt in order to use Dijkstra's algorithm, such as:

$$d(s) = 0 \qquad [3]$$

Distance from the starting point to itself is always counted as "0".

$$d(u) \qquad [4]$$

known shortest distance from the starting point (vertex s) to the random point (vertex u).

$$w(u, v) \qquad [5]$$

represents the weight of the edge between vertex u and vertex v.

At the end, we will also need Q also known as Priority Queue. “Q” is an unstable variable that changes in case, if:

$$d(f) + w(f, u) < d(u) \quad [6]$$

we will change Priority Queue. In simple words, Priority Queue is a variation that is currently optimal.

As priority queue is used in the static implementation of the algorithm, so using a retroactive priority queue we can dynamize the algorithm (15).

3.3.3.2 Solving TSP by Dijkstra’s Algorithm by Applying Hamiltonian cycle

Dijkstra’s algorithm is not directly connected with the TSP, however, there are some ways. For an example, converting the TSP into a graph problem is a way. By creating the circular model graph. Throughout the history of mathematics, there was this Hamiltonian cycle was proposed by many mathematicians. To use the Hamiltonian cycle, we must add more rules to Dijkstra’s algorithm such as:

1. Researcher can start from any vertex.
2. Addition of New condition: All vertices must be visited, and only once.
3. Priority Queue includes all vertices.

In transportation planning, determining the shortest travel time is affected by many logistics parameters. Locations in the transportation network can be weighted according to some criteria and these weights can be used in route planning. By calculating the shortest travel time for the determined routes, the most suitable cycle can be determined from the manufacturer to the customer in the logistic network. Besides, in case of uncertainty, decision-making processes can be improved by including fuzzy numbers. In this study, the shortest travel time on a time-dependent directed logistic network is examined. The original contribution of this paper is to combine three approach such as spherical bipolar fuzzy MCDM methodology on weighting the nodes of time-dependent digraph, minimum vertex degree algorithm to search fuzzy Hamiltonian cycles, and time-dependent Dijkstra’s algorithm to find the shortest travel distance (5).

In Mathematical terms, it means creating a concave polygon with the minimum perimeter.

3.3.4 Lin-Kernighan's Algorithm

Lin-Kernighan is an overwhelming algorithm that is more heuristic than the other ones. At the heart of the most successful tour-finding approaches to date lies the simple and elegant algorithm of Lin and Kernighan. This is remarkable, given the wide range of attacks that have been made on the TSP in the past three decades, and even more so when one considers that Lin and Kernighan's study was limited to problem instances having at most 110 cities (very small examples by today's standards) (1).

There is a set of cities. Let's denote the whole tour as:

$$\sigma = (\sigma_1, \sigma_2, \sigma_3, \dots . \sigma_n) \quad [7]$$

, σ_i means that i-th city that was visited. The TSP is now can be expressed as mathematical problem of minimization.

$$min_{\sigma} L(\sigma) \quad [8]$$

"L" is length function, and the main function can be described as:

$$L(\sigma) = \sum_{i=1}^{n} d(\sigma_i, \sigma_{i+1}) + d(\sigma_n, \sigma_1) \quad [9]$$

This expression shows the distance between the i-th and the $i + 1$-th cities but it is not the most important part. The most important part is the $d(\sigma_n, \sigma_1)$ part. It is because the distance between the last city and the first city is the only city that the researcher is not choosing from the matrix he has or provided. So, which means it will be very tricky if the distance between the last and the first city is statistically an outlier.

3.3.5 Excel Solver /Evolutionary/ program

Solver can use one of several solving methods. In the Solver Parameters dialog box, click the Select a Solving Method down arrow and select Simplex LP, GRG Nonlinear, or Evolutionary. Select the Simplex LP method if your worksheet model is linear. In the simplest possible terms, a linear model is one in which the variables are not raised to any powers and none of the so-called transcendent functions, such as SIN and COS, are used. Select the GRG Nonlinear method if your worksheet model is nonlinear and smooth. In general terms, a smooth model is one in which a graph of the equation used does not show sharp edges or breaks (8).

When the worksheet model or the data is nonlinear and non-smooth then choosing the evolutionary is obligatory. In our case, the worksheet will mainly include non-linear and non-smooth matrices, the evolutionary option works perfectly fine.

3.3.5.1 Steppes to gain the result.

Developed matrix that excluded the names and marked them numerically.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
1		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
2	1	0	430	1636	630	318	1001	238	219	463	655	260	984	371	430	553	560	311	1425	671	331	1336
3	2	430	0	1220	214	289	589	630	537	855	1108	500	531	357	266	643	1013	629	1039	413	784	883
4	3	1636	1220	0	1006	1334	635	1644	1582	1869	2291	1314	725	1402	1206	1583	2274	1702	211	981	1967	301
5	4	630	214	1006	0	503	371	638	751	863	1285	508	459	571	200	577	1204	843	795	617	961	988
6	5	318	289	1334	503	0	874	456	248	781	973	611	807	68	348	725	878	340	1321	353	649	1033
7	6	1001	589	635	371	874	0	1009	1122	1234	1656	879	195	949	571	948	1602	1214	424	583	1332	662
8	7	238	630	1644	638	456	1009	0	457	225	439	186	1153	609	494	479	462	549	1489	909	233	1569
9	8	219	537	1582	751	248	1122	457	0	682	874	479	989	180	596	772	779	92	1519	601	550	1281
10	9	463	855	1869	863	781	1234	225	682	0	531	355	1322	834	663	516	340	774	1658	1134	302	1738
11	10	655	1108	2291	1285	973	1656	439	874	531	0	741	1639	1026	1085	1074	191	966	2080	1326	324	991
12	11	260	500	1314	508	611	879	186	479	355	741	0	967	631	308	293	613	571	1303	913	417	1383
13	12	984	531	725	459	807	195	1153	989	1322	1639	967	0	809	659	1036	1544	1147	465	388	1315	529
14	13	371	357	1402	571	68	949	609	180	834	1026	631	809	0	416	793	931	272	1339	421	702	1101
15	14	430	266	1206	200	348	571	494	596	663	1085	308	659	416	0	377	990	688	995	679	761	1188
16	15	553	643	1583	577	725	948	479	772	516	1074	293	1036	793	377	0	856	864	1372	1056	710	1585
17	16	560	1013	2274	1204	878	1602	462	779	340	191	613	1544	931	990	856	0	871	2052	1231	229	1896
18	17	311	629	1702	843	340	1214	549	92	774	966	571	1147	272	688	864	871	0	1612	693	642	1373
19	18	1425	1039	211	795	1321	424	1489	1519	1658	2080	1303	465	1339	995	1372	2052	1612	0	853	1756	238
20	19	671	413	981	617	353	583	909	601	1134	1326	913	388	421	679	1056	1231	693	853	0	1002	680
21	20	331	784	1967	961	649	1332	233	550	302	324	417	1315	702	761	710	229	642	1756	1002	0	1667
22	21	1336	883	301	988	1033	662	1569	1281	1738	991	1383	529	1101	1188	1585	1896	1373	238	680	1667	0

Figure 1-Developed matrix that excluded the names and marked them numerically.

We need to calculate the objective function which is sum of all the edges. In mathematical sense, we are looking for the most ideal Hamiltonian Cycle. So, let's write it as:

$$S = \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} * x_{ij} \quad [10]$$

n- number of vertices in the graph (number of cities in this case, 21)

w_{ij}- weight of the graphs between vertex i and vertex j (city i and city j)

x_{ij}- decision variable [binary], in this case it must equal to "1" to include all the vertices (cities).

We need to create numerical sequence.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	1

Figure 2- Step 1

Keep in mind that we need to connect the last city to the first city in order to create loop. So, we need to put the first and last numbers same. In excel, just make it equal to the first number no matter what.

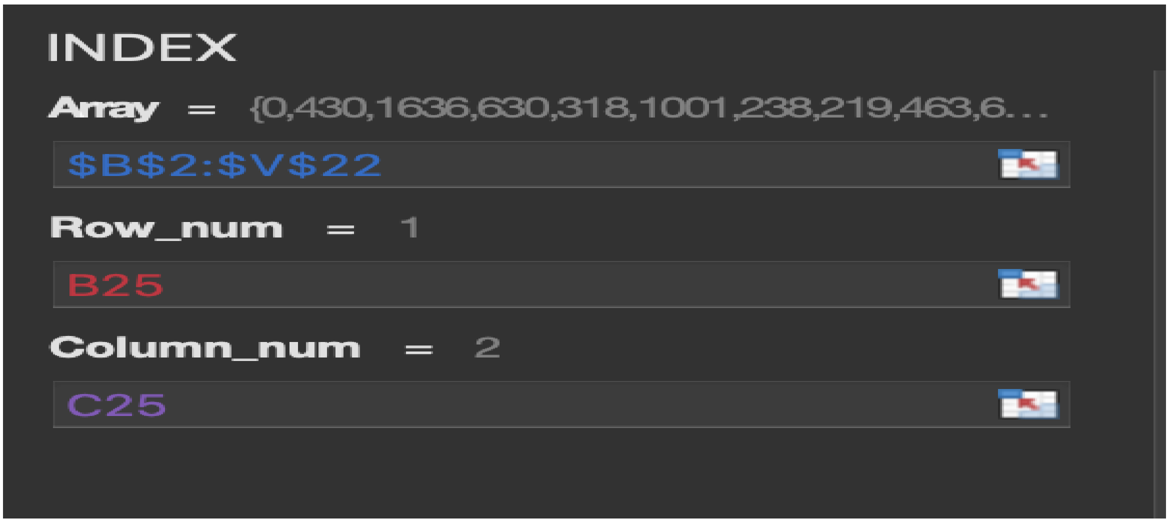

Figure 3- Step 2 Formula Builder View

By using Index function we can exploit the fact that we will pick only one number from every column and row.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
1		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
2	1	0	430	1636	630	318	1001	238	219	463	655	260	984	371	430	553	560	311	1425	671	331	1336	
3	2	430	0	1220	214	289	589	630	537	855	1108	500	531	357	266	643	1013	629	1039	413	784	883	
4	3	1636	1220	0	1006	1334	635	1644	1582	1869	2291	1314	725	1402	1206	1583	2274	1702	211	981	1967	301	
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8	7	238	630	1644	638	456	1009	0	457	225	439	186	1153	609	494	479	462	549	1489	909	233	1569	
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18	17	311	629	1702	843	340	1214	549	92	774	966	571	1147	272	688	864	871	0	1612	693	642	1373	
19	18	1425	1039	211	795	1321	424	1489	1519	1658	2080	1303	465	1339	995	1372	2052	1612	0	853	1756	238	
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22	21	1336	883	301	988	1033	662	1569	1281	1738	991	1383	529	1101	1188	1585	1896	1373	238	680	1667	0	
23																							
24																							
25		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	1
26		C25)																					

Figure 4- Step 2 worksheet view.

After these two steps, we need the current sum also can be called Initial Total Distance /ITD/.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
25		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	1
26		430	1220	1006	503	874	1009	457	682	531	741	967	809	416	377	856	871	1612	853	1002	1667	1336	
27																							
28																							
29							$\sum edges$			18219													
30										Total Distance													
31																							

Figure 5- Step 3 /Finding the Sum/

Now researcher can just click on the sum, which is 18219 in this case. And minimize the sum by using Solver Function in Data option.

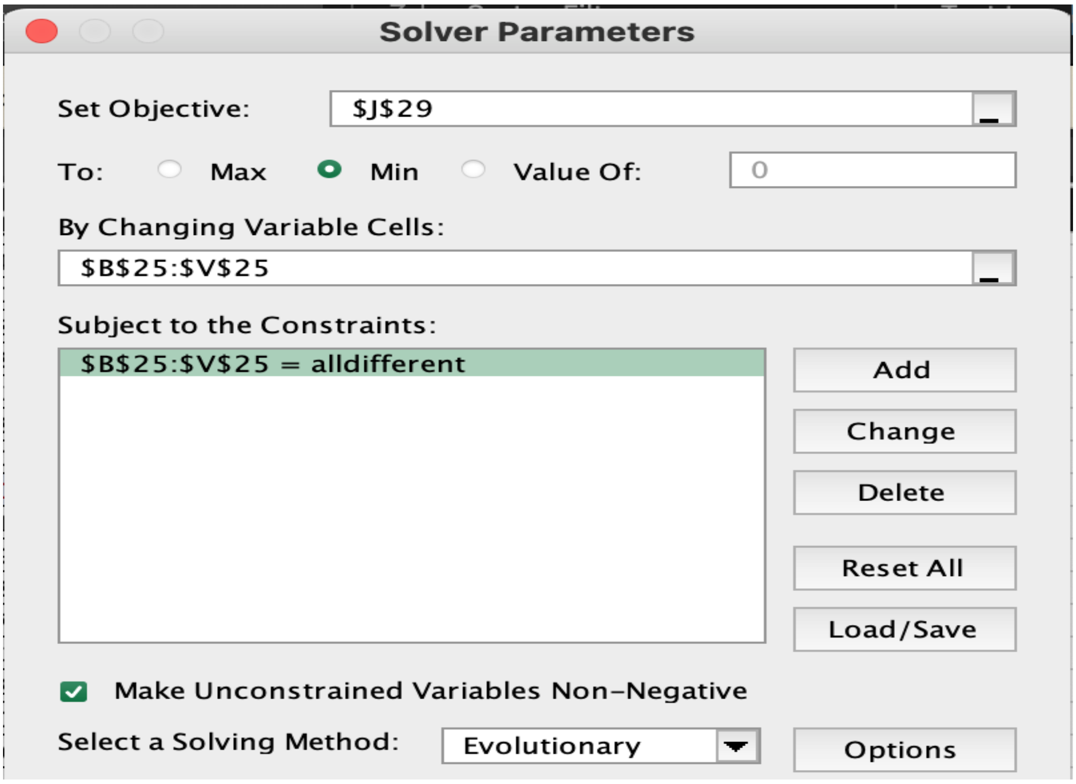

Figure 6- Final Step /Evolutionary Solver/

Choosing the (Figure.4) row in section "Changing Variable Cells" and in the "Subject to the Constraints". Setting the Objective for the Sum from the (Figure.5).

3.4 Logistics and Transportation significance

Logistics is essential topic for business planning process. It is also deeply connected with the transportation. Transportation is one of the main functions.

The nomenclatures of transport and logistics jobs are relatively numerous. They show a wide diversity of jobs. Some highlight jobs in both freight transport and passenger transport (10).

Carbon footprint in logistics transportation:

The logistics transport sector has an extensive environmental, social, and economic impact in society. Logistics and passenger transport by combustion vehicles contribute with about 25% to CO_2 emissions. Due notorious environmental degradation, regarding the increase in Greenhouse Gas Emissions (GGE), such as CO_2, several measures have been implemented (17).

3.4.1 Integrals of Logistics and Transportation Role

VCD is a crucial part of the logistics system and has always been a challenge in the field of logistics. With the popularization and acceleration of network and logistics information, the logistics system has undergone significant changes. Currently, with the rapid development of the retail industry and the rise of e-commerce, the frequency of delivering goods to urban centers is increasing. In recent years, the development momentum of VCD industry has been booming (18).

Logistics considers many variables, however, there are integrals that are:

- Customer Satisfaction
- Cost optimization
- Management of considerable risk
- Supply Chain Management
- Inventory Management
- Advantage seeking in Competitiveness.

Transportation in the logistics field is the biggest influencer. If not the biggest, then obviously one of the enormous factors. Transportation affects the price of the products, on the other hand, it also affects Inventory management, and competitive advantage in the long run. Customer Satisfaction can be lifted overall.

3.4.2 Characteristics of Current state in Mongolia

In Mongolian Vast land that has geographically 3 time zones and legally 2 time zones, distributing goods and services is the main task. Mongolia is indeed the least densely populated country in the world. So, there are threats where some people who live in far places from the capital could be in a position where they can’t be accessible for modern goods and services in time.

The Mongolian economy is subject to large supply and demand shocks. On the supply side, Mongolia is a landlocked country, experiences harsh winter conditions, and is geographically large all of which point to high transport costs and the potential for supply bottlenecks. On the demand side, mineral exports are a key driver of the economy but are also volatile due to global commodity price shocks. Indeed, the collapse of international copper prices in 2008 was the spark that ignited the ensuing economic crisis (2).

3.4.3 Roleplay in Supply Chain from logistic transportation system

An important concept within logistics transportation systems operations is logistics customer service. This concept is based on the overall scope of the supply chain. Traditionally it has been difficult for components of the supply chain to define their role in the overall customer service delivered to end-users. However, the growing trend is for a larger awareness of "their role not only with reference to trading partners but also to the end customer and at the point to the fact that logistics customer service in the supply chain functions as communicating vessels (9).

Transportation functions similar to the concept of the sword with a double edge. On the other hand, distributing new goods and services is a great method to withdraw expired or outdated goods.

3.4.4 Applying Mathematics in Logistics

The purpose of this study is to further develop the algorithmic foundations of economic and mathematical modeling of logistics networks based on advanced technologies that the digitalization process provides. Methods of mathematical modeling of flows of various resources in logistic networks, the structure of which is presented in the form of a graph, are used in the work (14).

In our everyday life logistics problem mathematical solution has always been the best. It is natural for people to understand. For transportation logistic instance, applying graph theory is pretty much suitable for any case.

4 Practical Part

4.1 Attributes of the issue

The capital city of Mongolia, Ulaanbaatar located in the heart of the country. Mongolia is the 18th largest country in the world. Separated into various regions such as steppes, desserts and mountainous terrains.

Mobicom is the biggest network company that operates in Mongolia. Main warehouse and the headquarter located in the capital. Mobicom's main scope is to firstly distribute their goods and services to the capital of the provinces.

There are 23 cities, including Ulaanbaatar. Our problem is to find the shortest paths to the other cities, our starting point is the capital Ulaanbaatar.
Central interception of the road system in Mongolia is situated in the capital.

Another Considerable calculation we can add is the diesel-consuming heavy vehicles that distribute the goods and products. For countries like Mongolia that don't have seaports /landlocked/. For companies, one of the main expenses is transportation cost.

4.1.1 Locations and names

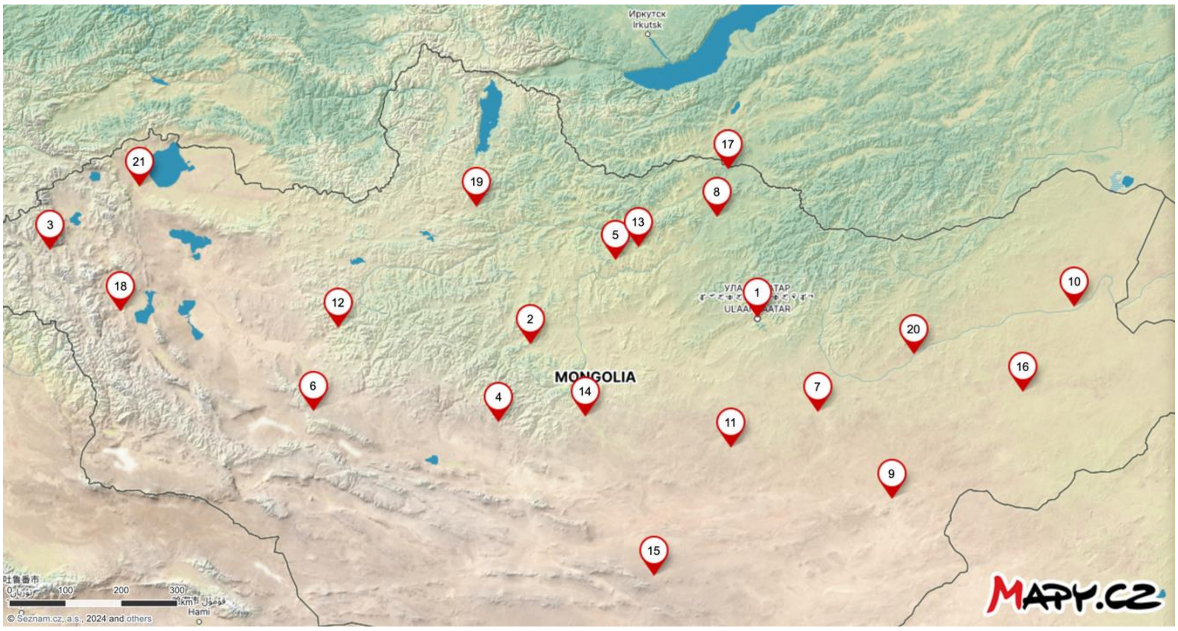

Figure 7-Geographical locations of the destinations

NAME OF THE TOWN /CAPITAL OF THE PROVINCES/	CORRESPONDING NUMBER
Ulaanbaatar	1
Tsetserleg	2
Ulgii	3
Bayankhongor	4
Bulgan	5
Altai	6
Choir	7
Darkhan	8
Sainshand	9
Choibalsan	10
Mandalgovi	11
Uliastai	12
Erdenet	13
Arvaikheer	14
Dalanzadgad	15
Baruun-Urt	16
Sukhbaatar	17
Khovd	18
Murun	19

Undurkhaan	20
Ulaangom	21

Table 1- Corresponding Table for destinations and their numbers

4.1.2 Initial table /distances between the cities/.

Table that includes raw data is essential for starting the iterations in any algorithm that helps us for gaining the optimal result.

City Name	Ulaanbatar	Tsetserleg	Ulgii	Bayankhongo	Bulgan	Altai	Choir	Darkhan	Saishand	Choibalsan
Ulaanbatar	0	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†
Tsetserleg	430	0	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†
Ulgii	1636	1220	0	¬†	¬†	¬†	¬†	¬†	¬†	¬†
Bayankhongo	630	214	1006	0	¬†	¬†	¬†	¬†	¬†	¬†
Bulgan	318	289	1334	503	0	¬†	¬†	¬†	¬†	¬†
Altai	1001	589	635	371	874	0	¬†	¬†	¬†	¬†
Choir	238	630	1644	638	456	1009	0	¬†	¬†	¬†
Darkhan	219	537	1582	751	248	1122	457	0	¬†	¬†
Sainshand	463	855	1869	863	781	1234	225	682	0	¬†
Choibalsan	655	1108	2291	1285	973	1656	439	874	531	0
Mandalgovi	260	500	1314	508	611	879	186	479	355	741
Uliastai	984	531	725	459	807	195	1153	989	1322	1639
Erdenet	371	357	1402	571	68	949	609	180	834	1026
Arvaikheer	430	266	1206	200	348	571	494	596	663	1085
Dalzandgad	553	643	1583	577	725	948	479	772	516	1074
BaruunUrt	560	1013	2274	1204	878	1602	462	779	340	191
Sukhbaatar	311	629	1702	843	340	1214	549	92	774	966
Khovd	1425	1039	211	795	1321	424	1489	1519	1658	2080
Murun	671	413	981	617	353	583	909	601	1134	1326
Undurkhaan	331	784	1967	961	649	1332	233	550	302	324
Ulaangom	1336	883	301	988	1033	662	1569	1281	1738	991

Figure 8- Distance Matrix first part

City Name	Mandalgovi	Uliastai	Erdenet	Arvaikheer	Dalanzadgad	BaruunUrt	Sukhbaatar	Khovd	Murun	Undurkhaan	Ulaangom
Ulaanbatar	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†
Tsetserleg	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†
Ulgii	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†
Bayankhongor	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†
Bulgan	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†
Altai	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†
Choir	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†
Darkhan	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†
Sainshand	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†
Choibalsan	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†
Mandalgovi	0	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†
Uliastai	967	0	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†
Erdenet	631	809	0	¬†	¬†	¬†	¬†	¬†	¬†	¬†	¬†
Arvaikheer	308	659	416	0	¬†	¬†	¬†	¬†	¬†	¬†	¬†
Dalzandgad	293	1036	793	377	0	¬†	¬†	¬†	¬†	¬†	¬†
BaruunUrt	613	1544	931	990	856	0	¬†	¬†	¬†	¬†	¬†
Sukhbaatar	571	1147	272	688	864	871	0	¬†	¬†	¬†	¬†
Khovd	1303	465	1339	995	1372	2052	1612	0	¬†	¬†	¬†
Murun	913	388	421	679	1056	1231	693	853	0	¬†	¬†
Undurkhaan	417	1315	702	761	710	229	642	1756	1002	0	¬†
Ulaangom	1383	529	1101	1188	1585	1896	1373	238	680	1667	0

Figure 9- Distance matrix second part

The full scaling matrice is around 21*21. As usual distance matrice the distance between the city and itself is 0, and the other part is the same as the reflection.

We need the matrix that is developed in order to use it in iterations.

City Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	0	430	1636	630	318	1001	238	219	463	655	260	984	371	430	553	560	311	1425	671	331	1336
2	430	0	1220	214	289	589	630	537	855	1108	500	531	357	266	643	1013	629	1039	413	784	883
3	1636	1220	0	1006	1334	635	1644	1582	1869	2291	1314	725	1402	1206	1583	2274	1702	211	981	1967	301
4	630	214	1006	0	503	371	638	751	863	1285	508	459	571	200	577	1204	843	795	617	961	988
5	318	289	1334	503	0	874	456	248	781	973	611	807	68	348	725	878	340	1321	353	649	1033
6	1001	589	635	371	874	0	1009	1122	1234	1656	879	195	949	571	948	1602	1214	424	583	1332	662
7	238	630	1644	638	456	1009	0	457	225	439	186	1153	609	494	479	462	549	1489	909	233	1569
8	219	537	1582	751	248	1122	457	0	682	874	479	989	180	596	772	779	92	1519	601	550	1281
9	463	855	1869	863	781	1234	225	682	0	531	355	1322	834	663	516	340	774	1658	1134	302	1738
10	655	1108	2291	1285	973	1656	439	874	531	0	741	1639	1026	1085	1074	191	966	2080	1326	324	991
11	260	500	1314	508	611	879	186	479	355	741	0	967	631	308	293	613	571	1303	913	417	1383
12	984	531	725	459	807	195	1153	989	1322	1639	967	0	809	659	1036	1544	1147	465	388	1315	529
13	371	357	1402	571	68	949	609	180	834	1026	631	809	0	416	793	931	272	1339	421	702	1101
14	430	266	1206	200	348	571	494	596	663	1085	308	659	416	0	377	990	688	995	679	761	1188
15	553	643	1583	577	725	948	479	772	516	1074	293	1036	793	377	0	856	864	1372	1056	710	1585
16	560	1013	2274	1204	878	1602	462	779	340	191	613	1544	931	990	856	0	871	2052	1231	229	1896
17	311	629	1702	843	340	1214	549	92	774	966	571	1147	272	688	864	871	0	1612	693	642	1373
18	1425	1039	211	795	1321	424	1489	1519	1658	2080	1303	465	1339	995	1372	2052	1612	0	853	1756	238
19	671	413	981	617	353	583	909	601	1134	1326	913	388	421	679	1056	1231	693	853	0	1002	680
20	331	784	1967	961	649	1332	233	550	302	324	417	1315	702	761	710	229	642	1756	1002	0	1667
21	1336	883	301	988	1033	662	1569	1281	1738	991	1383	529	1101	1188	1585	1896	1373	238	680	1667	0

Figure 10- Developed Matrix that is ready to put into the algorithms.

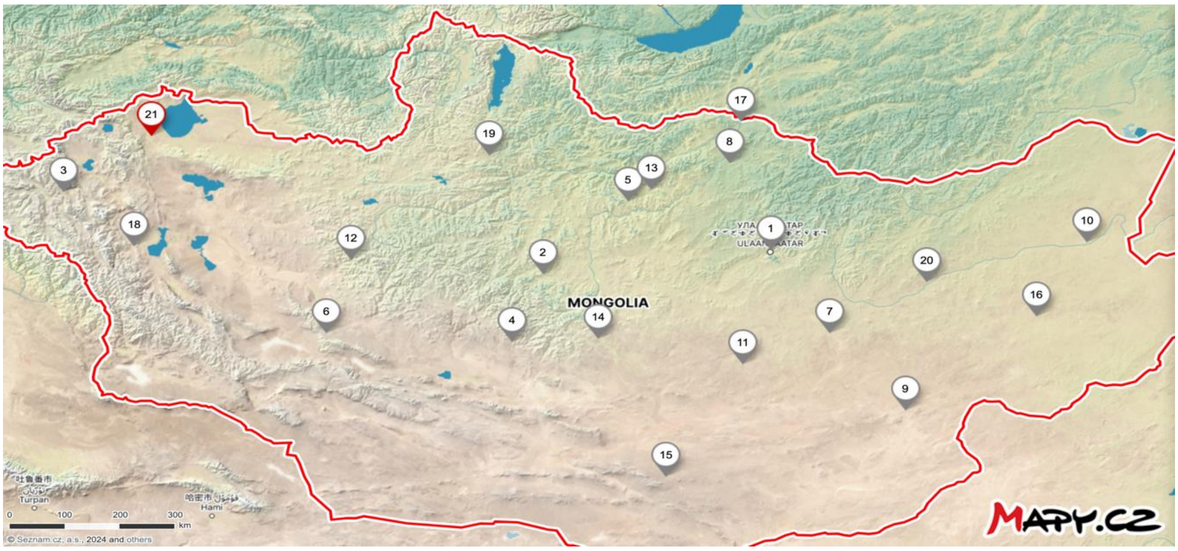

Figure 11- Cities and the relevant numbers (Source: mapy.cz)

4.2 Practical Calculations

Initial Distance is another term that is important to get result orientation. Result Orientation means feeling how the methods are reducing the total distance. It is not as important as the results. However, it is very useful for the researcher to make conclusions and evaluations in general.

[1] ⟶ [2] ⟶ [3] ⟶ [4] ⟶ [5] ⟶ [6] ⟶ [7] ⟶ [8] ⟶ [9] ⟶ [10] ⟶ [11] ⟶ [12] ⟶ [13] ⟶ [14] ⟶ [15] ⟶ [16] ⟶ [17] ⟶ [18] ⟶ [19] ⟶ [20] ⟶ [21] ⟶ [1]

ITD = 18219km

Reminder: This Value can be the sum of any TSP combination. The only reason I calculated this value is to get number orientation.

4.2.1 Nearest Neighbour Method

Result:

[1] ⟶ [5] ⟶ [13] ⟶ [8] ⟶ [17] ⟶ [3] ⟶ [18] ⟶ [21] ⟶ [6] ⟶ [12] ⟶ [19] ⟶ [2] ⟶ [4] ⟶ [14] ⟶ [15] ⟶ [9] ⟶ [16] ⟶ [10] ⟶ [20] ⟶ [7] ⟶ [11] ⟶ [1]

318+68+180+92+311+1702+211+238+662+195+388+413+214+200+377+516+340+191 +324+233+186+260=7619

{7619km} is the final result obtained from the method.

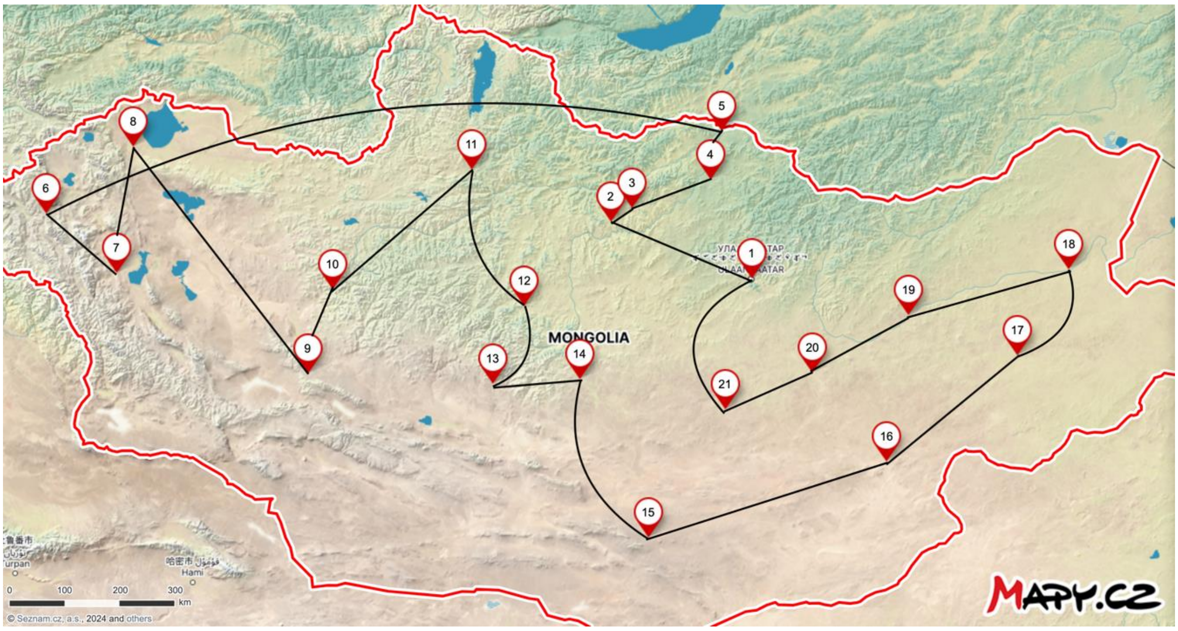

Figure 12- Graph Result of NNM (Source: mapy.cz)

4.2.1.1 Characteristics of NNM result

By creating this graph and observing the iterations, Nearest Neighbor method creates this odd edge that is very far from each other. In this case it was the [17] ⟶ [3] where it was 1702 km away from each other.

[17] is the most northern city Sukhbaatar, and the [3] is the most western city Ulgii.

NNM resulting sequence	*Loop cycle numbers according to the initial map*	*Name of the City*	*Distance from the previous city /km/*
1	1	Ulaanbaatar /Capital/	318
2	5	Bulgan	68
3	13	Erdenet	180
4	8	Darkhan	92
5	17	Sukhbaatar	1702

6	3	Ulgii	211
7	18	Khovd	238
8	21	Ulaangom	662
9	6	Altai	195
10	12	Uliastai	388
11	19	Murun	413
12	2	Tsetserleg	214
13	4	Bayankhongor	200
14	14	Arvaikheer	377
15	15	Dalanzadgad	516
16	9	Sainshand	340
17	16	Baruun-Urt	191
18	10	Choibalsan	324
19	20	Undurkhaan	233
20	7	Choir	186
21	11	Mandalgovi	260
1	1	Ulaanbaatar /Capital/	318

Table 2- NNM Graph result Table.

4.2.2 Dijkstra's algorithm

Result:

[1] ⟶ [17]⟶ [8] ⟶ [13] ⟶ [5] ⟶ [2] ⟶ [19] ⟶ [12] ⟶ [21] ⟶ [3] ⟶ [18] ⟶ [6] ⟶ [4] ⟶ [14] ⟶ [15] ⟶ [11] ⟶ [9] ⟶ [16] ⟶ [10] ⟶ [20] ⟶ [7] ⟶ [1]

311+91+180+68+289+413+388+529+301+211+424+371+200+377+293+355+340+191+324+233+238=6128km

{6128} km is the result of the Dijkstra's algorithm research.

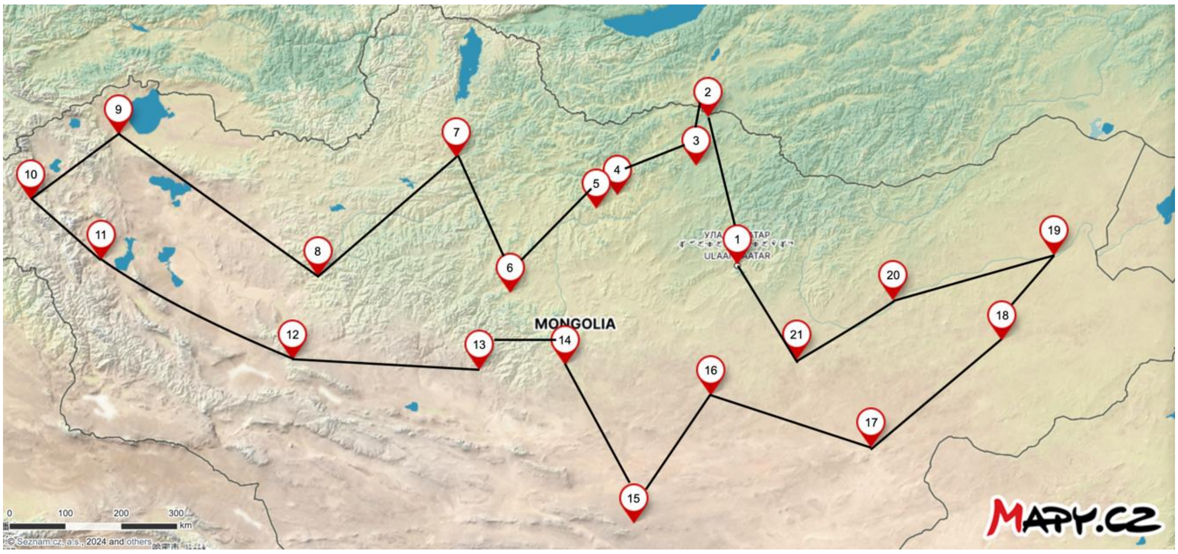

Figure 13- Graph Result in Dijkstra's Algorithm (Source: mapy.cz)

4.2.2.1 Characteristics of Dijkstra's result

This is the graph that Dijkstra's algorithm consists of. This graph consists of start the transportation from the Northern cities /capital of the provinces/, then heading to the western regions and curving from there to the southern and eastern cities.

Dijkstra's algorithm resulting sequence	*Loop cycle numbers according to the initial map*	*Name of the City*	*Distance from the previous city /km/*
1	1	Ulaanbaatar /Capital/	238
2	17	Sukhbaatar	311
3	8	Darkhan	91
4	13	Erdenet	180
5	5	Bulgan	68
6	2	Tsetserleg	289
7	19	Murun	413
8	12	Uliastai	388
9	21	Ulaangom	529
10	3	Ulgii	301
11	18	Khovd	211
12	6	Altai	424
13	4	Bayankhongor	371
14	14	Arvaikheer	200
15	15	Dalanzadgad	377
16	11	Mandalgovi	293
17	9	Sainshand	355
18	16	Baruun-Urt	340
19	10	Choibalsan	191
20	20	Undurkhaan	324
21	7	Choir	233
1	1	Ulaanbaatar /Capital/	238

Table 3- Dijkstra's Algorithm Graph result table.

This is the graph that Dijkstra's algorithm consists of. This graph consists of start the transportation from the Northern cities /capital of the provinces/, then heading to the western regions and curving from there to the southern and eastern cities.

4.2.3 Lin-Kernighan Algorithm

Result:

[1] ⟶ [15] ⟶ [11] ⟶ [14] ⟶ [2] ⟶ [4] ⟶ [6] ⟶ [12] ⟶ [18] ⟶ [3] ⟶ [21] ⟶ [19] ⟶ [5] ⟶ [13] ⟶ [8] ⟶ [17] ⟶ [7] ⟶ [9] ⟶ [16] ⟶ [10] ⟶ [20] ⟶ [1]

553+293+308+266+214+371+195+465+211+301+680+353+68+180+92+549+225+340+191+324+331=6510

{6510km} is the solution obtained from Lin-Kernighan Algorithm /heuristics/.

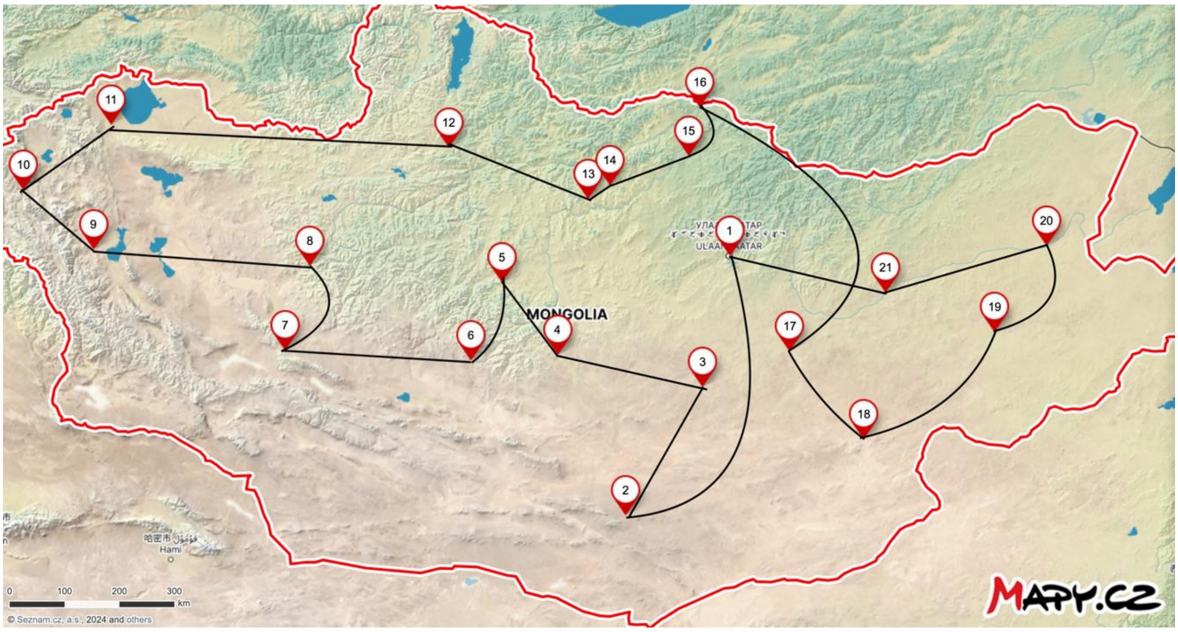

Figure 14- Graph Result in Lin-Kernighan (Source: mapy.cz)

4.2.3.1 Characteristics of Lin Kernighan's result

Lin-Kernighan's graph had 1 intercepting between the roads between [17] ⟶ [18] and [21] ⟶ [1] . This graph starts from going to the most southern city into travelling towards back to the north then transposes into western regions, this resulted the special interception due to the geographical condition.

Lin-Kernighan's algorithm resulting sequence	*Loop cycle numbers according to the initial map*	*Name of the City*	*Distance from the previous city /km/*
1	1	Ulaanbaatar /Capital/	553
2	15	Dalanzadgad	293
3	11	Mandalgovi	308
4	14	Arvaikheer	266
5	2	Tsetserleg	214
6	4	Bayankhongor	371

7	6	Altai	195
8	12	Uliastai	465
9	18	Khovd	211
10	3	Ulgii	301
11	21	Ulaangom	680
12	19	Murun	353
13	5	Bulgan	68
14	13	Erdenet	180
15	8	Darkhan	92
16	17	Sukhbaatar	549
17	7	Choir	225
18	9	Sainshand	340
19	16	Baruun-Urt	191
20	10	Choibalsan	324
21	20	Undurkhaan	331
1	1	Ulaanbaatar /Capital/	238

Table 4- Lin-Kenighan's Algorithm Graph result table.

4.2.4 Excel Solver Evolutionary method

Result:

[1] ⟶ [20] ⟶ [10] ⟶ [16] ⟶ [9] ⟶ [7] ⟶ [11] ⟶ [15] ⟶ [14] ⟶ [4] ⟶ [6] ⟶ [12] ⟶ [18] ⟶ [3] ⟶ [21] ⟶ [19] ⟶ [2] ⟶ [5] ⟶ [13] ⟶ [17] ⟶ [8] ⟶ [1]

331+324+191+340+225+186+293+377+200+371+195+465+211+301+680+413+289+68 +272+92+219+331=6043

{6043km} is the solution that was given by the Excel Solver /Evolutionary/.

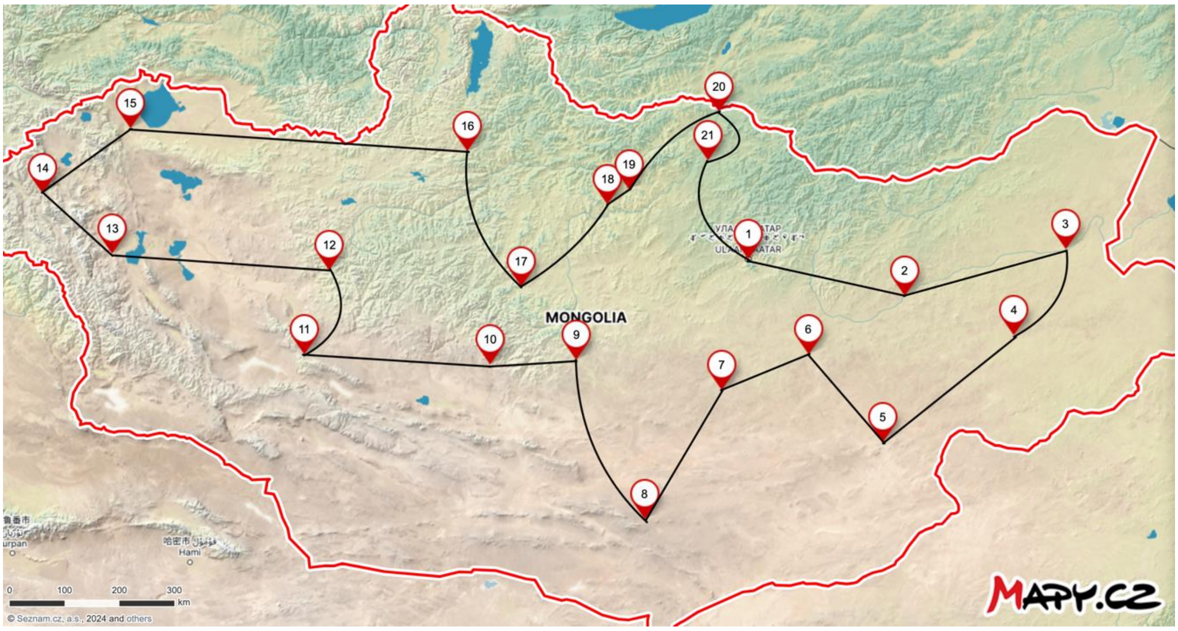

Figure 15- Graph Result obtained from Excel Solver /Evolutionary/ (Source: mapy.cz)

4.2.4.1 Characteristics of Excel Solver /Evolutionary/ result

Excel Evolutionary Solver is the strong engine that solves with the immense power of matrix analysis. The end value /final solution/ of this method is the most optimal solution that this program can give, different from the other methods such as NNM and Dijkstra's, Lin-Kernighan where there could be deeper solution.

Excel solver /Evolutionary/ resulting sequence	*Loop cycle numbers according to the initial map*	*Name of the City*	*Distance from the previous city /km/*
1	1	Ulaanbaatar /Capital/	331
2	20	Undurkhaan	324
3	10	Choibalsan	191
4	16	Baruun-Urt	340
5	9	Sainshand	225
6	7	Choir	186
7	11	Mandalgovi	293
8	15	Dalanzadgad	377
9	14	Arvaikheer	200
10	4	Bayankhongor	371
11	6	Altai	195
12	12	Uliastai	465
13	18	Khovd	211
14	3	Ulgii	301
15	21	Ulaangom	680
16	19	Murun	413
17	2	Tsetserleg	289
18	5	Bulgan	68
19	13	Erdenet	272
20	17	Sukhbaatar	92
21	8	Darkhan	219
1	1	Ulaanbaatar /Capital/	331

Table 5- Excel Solver /Evolutionary/ graph result table.

4.2.5 Calculation for Transportation cost

In Mongolia, large scaling companies used to exploit truck for the transportation and distribution. It is the main channel to distribute and retrieve.

In Mongolia there are major 6 types of medium trucks from 5 different company are recorded in the government report.

	On local roads	
Truck model	In the warm season /April till October/ $l/100km$	In the cold season /November till March/ $l/100km$
Volvo FH440	37,0	44,4
Volvo FH610	38,5	46,2
Sinotruk	34,2	41,0
Scania P420	36,0	43,2
Daewoo F3DEF	34,5	41,4
CAMC HN4250	35,0	42.0
	Δ35.87	Δ43.03

Table 6- Standard norms of fuel consumption. /Source: Online Source (1) /

4.2.5.1 Cost calculation

The current (11th of March,2024) average price rate of diesel per liter in Mongolia is: (31.584 CZK, 1.249 EUR)

The expense of Distribution and Retrieval of the goods and products in terms of diesel consumption can be expressed in mathematical equations like:

$$Total\ Cost = [\frac{Total\ Distance}{100km} Average\ Consumption\ Per\ 100km * Price] \quad [11]$$

Using the most feasible solution obtained from the previous part would suit more which will be the Excel Solver /Evolutionary/ result: {6043km}

A
$$Total\ Cost = \frac{6043km}{100km} * 35.87 * 31.584CZK \approx 68462.24CZK \quad [12]$$

B
$$Total\ Cost = \frac{6043km}{100km} * 43.03 * 31.584CZK \approx 82127.97CZK \quad [13]$$

5 Results and Discussion

Throughout this thesis practices I have used 4 methods to obtain the various results from all of them. I have used methods such as NNM, Dijkstra's application according to the Hamiltonian Cycle, Lin-Kernighan's' Algorithm /heuristics/, Excel Solver /Evolutionary/ so far.

5.1 Results

Method Number	Methodology Nomenclature	Obtained Optimal Result
1	Nearest Neighbor Method	7619km
2	Dijkstra's Algorithm	6128km
3	Lin-Kernighan's Algorithm	6510km
4	Excel Solver /Evolutionary/	6043km

Table 7- Final Results

5.1.1 Specialty of the methods and the comparisons

All the methods have their own specialty and priority for their vertex choice.

The nearest neighbor method is more suited for problems with a small number of destinations. In this case, most of the downsides of NNM have occurred. Such as the greedy nature of the algorithm and the Inability to correct the mistakes and performance for the large number of cities.

Dijkstra's Algorithm that exploited Hamiltonian Cycle rules have given good result, surprisingly. Main concern was the last and the first vertices that supposed to be connected at the end. However, in this problem first and the last vertices ended up in very decent position. It is purely related to the characteristic of the distance matrix.

Lin Kernighan's algorithm in general is often the choice of the researchers due to its nature. This algorithm is the only method among the other ones in this thesis work that constructs the vertices by calculating the sum of a combination of graphs.

Excel Solver /Evolutionary/ program is the only one that calculates the whole raw matrix that was provided by the researcher. Setting up constraints and choosing the decision variables are just enough for this method.

5.1.2 Most feasible approximate solution

The most optimal result observed from the recent practical part was presented by Excel Solver /Evolutionary/, touring around Mongolia by crossing all the main cities within only 6048km.

Optimal Result: {6048km}

5.1.3 Cost Calculation for Diesel Consumption

In terms of expenses, medium-truck diesel consumption is quite high. For a country like Mongolia the temperature swings enormously during the seasons calculating it in 2 circumstances is suitable, I hope. Warm seasons and Cold seasons are quite different from each other economically.

A. During warm seasons the optimal way to go around all the cities costs 68462.24 CZK. For the other nationals it is [2707 EUR], In Mongolian currency it is approximately [7,771,770 MNT].
B. During cold seasons the optimal way to go around all the cities costs 82127.97 CZK. For the other nationals it is [2883 EUR], n Mongolian currency it is approximately [8,285,730 MNT].

Conclusion

5.2 Research Objectives

This thesis's main object is to optimize the distributing and retrieving route of Mobicom Corporations goods and services in Mongolia. The main challenge was to find the minimum distance touring route. Finding the solution influences the whole corporation on a large scale. For this case the TSP or Traveling Salesman Problem fits perfectly, in terms of mathematics it is called a weighted graphs problem.

5.3 Key Discoveries

I have obtained 4 results from the methods I have used. Three of the methods are natural for researchers who is looking through TSP. Remaining one is not familiar, however, I applied it to gain solution.

NNM is the simplest and the most natural method that connects the nearest city that haven't visited yet. In this research, result was:

Initial Distance	Final Distance /Result/
18219km	7619km

Table 8- NNM result compared to ITD.

Dijkstra's Algorithm with Hamiltonian Cycle rules, aiming the outermost cities /Prior queue/ by doing that visiting the cities that are on the road. Simply creating the concave polygon that's perimeter is small.

Initial Distance	Final Distance /Result/
18219km	6138km

Table 9- Dijkstra's result compared to ITD.

Lin-Kernighan's Algorithm's findings was calculated from the initial distance by heuristic approach by changing the edges between the vertices.

Initial Distance	Final Distance /Result/
18219km	6510km

Table 10- Lin-Kernighan's result compared with ITD.

Excel Solver's /Evolutionary/ result. Solver calculated the result in approximately 7 minutes.

Initial Distance	Final Distance /Result/
18219km	6043km

Table 11- Excel Solver /Evolutionary/ result compared to ITD.

5.4 Implications of the findings

5.4.1 Implications In General

By finding a reasonable optimal solution Mobicom Corporation will be able to choose the transportation path that helps to distribute and retrieve the goods and products also it will be a lot more flexible for showing services to the customers.
From this research, there will be many things that could benefit from it. Not only just the Mobicom Corporation but also the Infrastructure of Mongolia and tourism can be affected significantly.
Also, another benefit is the reduction of environmental impacts such as fuel consumption and emissions caused by vehicles.

5.4.2 Implications in Economics

Mongolian Economics in terms of size it is small. For foreign strong currency reliant Economy of Mongolia, we have to keep in mind that small efficiencies like optimal route loop system can impact the whole economy.

5.5 Validity of the Results

Methods I have used in this work are heuristic methods, except Excel Solver obviously. As I mentioned heuristic algorithms often gain results from good intuitions and experiences. For Excel Solver /Evolutionary/ 6048km is the optimal value that the program can give. Run the Excel Solver with its full duration of calculation will end up giving the final most optimal solution that Excel considers.
For the other remaining methods NNM and Dijkstra's Algorithm and Lin-Kernighan's Algorithm. All of them can be optimized further. Every heuristic algorithm can be developed but as for today these results NNM [7619km] Dijkstra's [6128km] and Lin-Kernighan's [6510km] were the best I can achieve.

5.6 Limitations of the research

NNM and Dijkstra’s Algorithm and Lin-Kernighan Algorithm are based on a heuristic approach during the calculation part. So, the researcher must rely on his/her own intuition and logic.

The most problematic pressing issue that occurred during the calculation part was Dijkstra’s Algorithm application by using the Hamiltonian cycle. From the beginning, I knew that Dijkstra’s Algorithm was more suitable for Shortest Path problems that have a start point and end point that is different. Hamiltonian cycle is a graph cycle that visits every vertex. To use Dijkstra’s algorithm, I realized I must set direction so that Dijkstra’s Algorithm can move. Logically choosing the most outermost cities genuinely worked. In this case, the Dijkstra started ignoring the nearest cities and focused on more outermost cities, so that there would be no problem with the last city being far away from the starting city Ulaanbaatar, because I visited all the outermost cities so that inner cities that close to Ulaanbaatar is left.

NNM and Lin-Kernighan’s algorithms are both greedy and simple to use. Nothing new of thinking happened during the calculations. However, I started understanding that both methods have a high chance of stuck in a remote city.

For an Excel Solver /Evolutionary/. The more time the researcher runs the Solver the result will be more optimized.

In the sense of Diesel Consumption Expenses calculation, most of the variables are not constant which means it will change in the future, however, the most integral 2 variables and their ratio will never change is the biggest part. Which are “100km” (the measuring constant parameter) and the feasible solution from Excel Evolutionary estimation “6043km”. The ratio of 60.43 is kind of locked in.

5.7 Future Insights

I think Dijkstra’s Algorithm usage in creating the Hamiltonian cycle could be a great method for similar cases like Mongolia. I think Mongolia’s geographical characteristics are simple due to the city locations even from the matrix we have observed that the distances are distributed nicely. The Main weapons of this method are intuition and observation of the other methods and understanding where the other methods are messing. Unfortunately, for this research, this method didn’t get me the most optimal solution however Dijkstra’s

Algorithm beats the other two methods /NNM and Lin-Kernighan's/ that have traditionally solved TSP for the last 100 years.

5.8 End Note

Mankind has been seeking optimal things throughout human history. Thankfully our ancestors left various methods that can solve our present days' problems. The beauty of human logic at its finest is here with us. Adopting and developing the ideas that our past left us is our power.

In conclusion, this research helped to understand and demonstrate the "Designing the Optimal Transportation for Mobicom Corporation in Mongolia" problem. Advancing our understanding of optimization in "graph theory and traveling salesman problem". The calculations that I have made to achieve the results have strengthened my experience and intuitions in the mathematics field. I have understood that optimization problems aren't just mathematical problems, indeed it is our society's problem. In the future I sincerely hope there will be similar works will be published. I hope this research will seduce other researchers to solve the same problems as this one. It is my hope that this work inspires further curiosity and sparks meaningful dialogue among scholars and practitioners alike, ultimately leading to transformative advancements in the Traveling Salesman Problem and Transportation Optimization. On the other hand, not just scientific researchers but the business planners and people who want to make tours around Mongolia can use the results as their brochure. I sincerely hope that my work will spread in the future.

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7 List of pictures, tables and abbreviations

7.1 List of pictures

7.2 List of tables

7.3 List of abbreviations

MCDM – Multi Criteria Decision Making

MCDA – Multi Criteria Decision Analysis

TSP – Travelling Salesman Problem

NNM – Nearest Neighbor Method

GGE – Green Gas Emission

VCD – Vehicle Transportation and Distribution

ITD – Initial Total Distance

7.4 List of formulas and equations

I. Kernel’s Formula
II. Dijkstra’s Graph
III. Random vertex distance to itself
IV. Shortest distance between the starting vertex, goal vertex
V. Distance between connected two vertices.
VI. Priority Queue changing condition.

VII. Graph set of cities.
VIII. Objective Function
IX. Extension of the Objective Function
X. Hamiltonian Cycle Function
XI. Total Cost Formula
XII. Total Cost for warm season period
XIII. Total Cost for cold season period