**Czech University of Life Sciences**

**Faculty of Economics and Management**

**Department of systems engineering**

**Diploma thesis**

# Optimization of Transportation Routes between Customers and their Suppliers

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# CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

## Department of Systems Engineering

## Faculty of Economics and Management

# DIPLOMA THESIS ASSIGNMENT

Hermová Petra

European Agrarian Diplomacy

Thesis title

**Optimization of Transportation Routes Between Customers and their Suppliers**

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**Objectives of thesis**

The aim of this work is to propose possible solutions for transportation routes between a Taiwanese company, Polet Wunik International Ltd., its suppliers and customers. Polet Wunik International Ltd. controls its entire supply chain management system. The company provides transportation of goods from suppliers to customers between the whole world market and Taiwan and the Chinese market and vice versa.

**Methodology**

The methodology is based on the literature study and the data gathering. On a very large extent, the literature will be represented by textbooks issued by the Czech University of Life Sciences in Prague and the monograph on logistics.

The practical part will include an integral cooperation with the owner of Polet Wunik International Ltd., Mr. Yuan-ho Wu, who is the CEO of the company and actively engages the major clients of the company.

A big part will consist in the application of some optimization methods to specific cases of transportation between Polet Wunik International Ltd. and Czech companies that cooperate with each other.

**Schedule for processing**

Literature research: 06/2011 to 12/2012

Practical part: 09/2011 to 02/2013

Consultation and cooperation with Taiwanese companies: 09/2011 to 06/2012

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**The proposed extent of the thesis**

60 - 80 pages

**Keywords**

Logistics, suppliers, customers, traveling salesman problem, optimization methods, transportation, outsourcing

**Recommended information sources**

1.ZÍSKAL, J., HAVLÍČEK, J.: Ekonomicko matematické metody II – Studijní texty pro distanční studium. Vydání druhé, 2. dotisk: skriptum, ČZU, PEF, Praha 2003, ISBN 80-213-0664-5
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8. http://www.pwiss.com/EN/PWISS.html -the webpage of the Taiwanese company
Other literature as needed

**The Diploma Thesis Supervisor**

Kučera Petr, RNDr., Ph.D.

**Last date for the submission**

March 2013

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Prague February 28. 2013

Declaration of originality

I declare that my thesis “Optimization of Transportation Routes between Customers and their Suppliers " I developed independently under the leadership of the thesis and using literature and other information sources that are cited in the work and listed in the bibliography at the end of the work. As the author of the thesis further declare that I am related to its creation failed to the copyrights of third parties.

In Prague, March 22, 2013 ______________________________

Acknowledgement

It is my pleasure to acknowledge the invaluable help of my supervisor RNDr. Petr Kučera with scientific expressions and expert advices important for elaboration of my diploma thesis. My thanks also belong to Mr. Yuan-ho Wu, Ing. Radek Slepička and Ing. Michal Leština. They provide me useful information and practical advices.

# Optimization of Transportation Routes between Customers and their Suppliers

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# Optimalizace dopravních tras mezi zákazníky a jejich dodavateli


**Summary**

This diploma thesis is dedicated to the optimization of transportation routes for the Taiwanese company called Polet Wunik that facilitates the collaboration suppliers and consumers for its clients. The thesis deals with specific real cases where the Taiwanese company cooperates with Czech companies.

The first part is devoted to the literature review, which describes the optimization methods that can be used to calculate the optimization of routes to use. The second part describes all the three companies that need to optimize its transportation routes, which are a big part of its cooperation.

The results of this thesis are designed for companies that utilize the proposed solution for its logistics business, where the main emphasis is on reducing costs and compliance its requirements for timely delivery of goods ordered.



**Keywords:** Logistics, suppliers, customers, traveling salesman problem, optimization methods, transportation, outsourcing

**Souhrn**

Diplomová práce je věnována problematice optimalizace dopravních tras pro taiwanskou společnost Polet Wunik, která zprostředkovává dodavatelé a spotřebitelé pro své klienty. Tato diplomová práce se zabývá konkrétními reálnými případy, kde taiwanská společnost spolupracuje s českými společnostmi.

První část diplomové práce je věnovaná literární rešerši, kde jsou popsány optimalizační metody, které lze pro výpočet optimalizace tras používat. V druhé části práce jsou popsány všechny 3 společnosti, které potřebují optimalizovat dopravní trasy, které jsou velkou součástí jejich vzájemné spolupráce.

Výsledky této diplomové práce jsou navrhnuty společnostem, které využijí navrhované řešení logistiky pro jejich obchod, kde je kladen hlavní důraz na snížení nákladů a také dodržení jejich požadavků pro dodání včas objednaného zboží.

**Klíčová slova:** Logistika, dodavatelé, zákazníci, okružní dopravní problém, optimalizační metody, doprava, outsourcing

# 1 Introduction

Nowadays every business in the world is trying to have the lowest costs to save money. There are many tools for companies to save money. The companies can change its suppliers, do business in the international market, change strategies but all of them need a good logistic system.

The business world is developing very fast recently and also dangerous in the same time. Companies need to make choices every day. Some companies choose suppliers from Asian market because the costs are cheaper in some Asians countries. But there can also be problems for smaller companies which do not have its own department dealing with finding new suppliers.

In this thesis we deal with so-called supply chain management (SCM) - The literature is replete with buzzwords such as: integrated purchasing strategy, integrated logistics, supplier integration, buyer supplier partnerships, supply base management, strategic supplier alliances, supply chain synchronization and supply chain management, to address elements or stages of this new management philosophy (Tan et al., 1998a; New, 1997; La Londe and Masters, 1994) (European Journal of Purchasing & Supply Management, 2001, http://www.sciencedirect.com/).

Companies can cooperate with specialized companies which are doing supply chain management. Thanks to these companies, the firms can save time, money and make sure that the firm will have trustful suppliers because SCM companies guarantee that the company will care about its orders to be exactly the one like its clients need.

SCM companies are also taking care of the logistic system between suppliers and its clients. This is one of the most important parts of the order because SCM companies need to fulfill requirements from its clients (time, costs and places).

In this diploma thesis we cooperate with Taiwanese company and we will create a logistic system for two Czech clients which are using SCM company services.

The first client Šumavský pramen Inc. orders goods from Taiwan to Czech Republic and the second client BUSHMANN will provide its products to the Taiwanese market. By using optimization methods transportation routes between Taiwan and Czech Republic and vice versa will be optimized.

# 2 Objectives of Thesis and Methodology

The Taiwanese Company Polet Wunik International Ltd. heading in Taipei provides supply chain management for clients from around the world. This diploma thesis is focused on two new clients from Czech Republic, but its businesses are different. One company wants to enter the Taiwanese market with Czech goods and the second company wants to innovate its business with Taiwanese (Chinese) products. The goal of this diploma thesis is to suggest and optimize a logistic system for its business from Taiwan to Czech Republic and vice versa. These logistics contains the way from supplier to the final consumers. The optimization is going to be solved by using special methods.

The methodology consists from studying and understanding expertly literature which helps us to create and optimize our cases. The main sources belong to the scriptum from Czech University of Life sciences in Prague and expertly books which are focused on logistics and traveling salesman problem.

For the practical part, an important element was the cooperation with the chief executive officer (CEO) from Polet Wunik International Ltd. Mr. Yuan-ho Wu and Ing. Radek Slepička and workers from Czech companies' Šumavský pramen Inc. and BUSHMANN. Those companies have contracts with each other and the company need to build the logistic system for its order. In this diploma thesis we will present some optimization methods that will be introduced to the above mentioned companies for its next step: the realization of the business.

# 3 Literature Research

**Overview and description of optimization methods**

## 3.1 The use of operations research in transport logistics

Logistics is a new direction of thinking (that is) focused on satisfying customer needs. This effect is trying to achieve with the greatest flexibility and economy. Methods of operational analysis (OA) may be used in various articles tangible and intangible logistics chain that leads from extraction sites raw materials, through manufacturing and distribution organization up to the points of final consumption products (Získal, Brožová, 1998, p 61).

In promoting OA methods in logistics it is necessary to consider the vagueness of the concept ,,optimal“. The goal of most methods applied in OA is to reduce logistics costs at all stages of the logistics chain that precede the final consumption of products by customer. In today's market economy, the market seller becomes a buyer's market and requirements for product quality, speed and conditions of their delivery dictates the customer in an environment of competition between generation, distribution and selling organizations (,,our customer - our master"). It is therefore desirable to achieve not the minimum, but reasonably low costs, providing quick enough to meet customer needs (Získal, Brožová, 1998, p 61).

Traffic forwarding and logistics are among the numerous applications of logistics. It coordinates, synchronizes and optimizes the movement of consignments in transport network from the point of entry to the consignee. Its objective is the cost-effective and flexible satisfaction of the customer (Získal, Havlíček, 2003, p 58).

In the field of transportation there are a number of models that have been developed and can be used in logistics. The models display and explore various situations that may arise in transportation systems (e.g. direct traffic models, transit traffic models, transport with various means of transport, traveling salesman problems etc.) (Získal, Havlíček, 2003, p 58).

### 3.1.1 Basic concepts of logistics

To understand the problems of logistics, it is important to formulate basic terms of logistics, such as the logistics system, logistics chain and the concept of logistics itself.

The logistics system is a scientific discipline concerned with the solution coordination and synchronization chains tangible and intangible (i.e. information, monetary) transactions that arise as a result of the division of work, and which are connected with the production and circulation of a final production (Získal, Havlíček, 2003, p 59).

In essence, a new interconnection logistics familiar things consists of coordination, synchronization, and the overall (global) optimization tangible information and financial processes chained on the principle of division of labor in the manufacture and distribution of the final products. Goal is flexible and cost-effective manner to satisfy the customer (Získal, Brožová, 1998, p 61).

The logistic system is effectively an ordered set of all technical resources, equipment, buildings, roads and staff involved in the implementation of logistics chains. Logistic system can be regarded as a special multisystem kind, which we define as technical - technological, information communication and management system. The aim of the logistics system of the company is consolidating and strengthening the position of the enterprise as an economic entity to market (Získal, Havlíček, 2003, p 59).

The logistics chain is made up of sub of tangible, information, and other cash flows that occur between the different subsystems in production, transport, forwarding and trade (Získal, Havlíček, 2003, p 59).

### 3.1.2 Logistics in transport

Transportation logistics deals with coordination, synchronization, and overall optimization of all tangible and intangible processes in moving shipments in the transport network. In solving problems includes handling, storage, packaging and servicing. Key element of the whole transport chain is the customer (Získal, Havlíček, 2003, p 60).

The development of transportation logistics is determined by the level of transportation infrastructure given state or region. Traffic is growing sectors of the economy and demand for it continuously increases. The increase in demand for transportation is caused by changes in the structure of the manufacturing industry, changes in methods of production, reducing the size and increasing the supply of frequency, increase the share of the service sector (occupational mobility) and demographic changes (higher proportion of passenger cars and the development of travel). In the next period is to be expected to come with further development of road transportation (particularly truck) and combined transportation in the presence of the railroad (Získal, Havlíček, 2003, p 60).

The transport logistics is a concept of a sequence of tasks and sub-processes, which leads to minimizing the cost of logistics chains when the desired efficiency. Promote certain technologies, such as logistics ,,Just in Time“. These very frequent pickups at exactly the agreed deadlines place high demands on quality of service. Logistics has not its own methodological apparatus, using a variety of methods of mathematical modeling and simulation, various methods such as operational analysis, value analysis methods, etc. (Získal, Havlíček, 2003, p 60).

Classical transport problem is the demand for efficient transport (while minimizing transportation costs) homogeneous product from suppliers known capacity customers with known requirements for a given cost (or distance) between the supplier and customer locations (Získal, Havlíček, 2003, p 60).

Transportation with transit assumes no direct transport, but transit station (intermediate storage). Where known transport rates between all stations, the question is how to allocate transportation of goods from suppliers through intermediate stores to consumers that the total transportation costs were minimal (Získal, Brožová, 1998, p 64).

Models of transport problems can be in terms of the complexity of traffic distinguished according to the terms of number of stages and according to the size of the model. Degrees transport is defined according to the number of transits, places through which transport takes place and to be optimally chosen to individual routes. The size of transport jobs represents the type of vehicle, type of material transported, the time required for transport, etc., so that the transport system allows optimize also the means of transportation (Získal, Brožová, 1998, p 64).

### 3.1.3 Models of optimizing direct routes

This group comprises mainly two models of graph theory. The first one is the problem of finding the shortest path between any two points in the transport network with a length labeled roads. The problem is solved finding the shortest path in a graph (Získal, Brožová, 1998, p 64).

In the case that the individual communication evaluated their permeability, which enabling per unit time passing only a certain number of vehicles is problem of the theory of flows in networks, and the purpose is to find the maximum flow, i.e. the maximum throughput of all considered routes connecting two nodes (station) (Získal, Brožová, 1998, p 64).

## 3.2 Traveling salesman problem

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 (Gregory, Abraham, 2007, p 1).

The name ´´traveling salesman problem´´ for the optimization problem of our discussion is believed to have originated in the United States. Perhaps the first report using this name was published in 1949. However, it would be reasonable to say that a systematic study of the TSP as a combinatorial optimization problem began with the work of Dantzig, Fulkerson and Johnson. The survey papers and the books summarize various developments on the subject (Gregory, Abraham, 2007, p 2).

The probabilistic traveling salesman problem (PTSP0 is essentially the traveling salesman problem (TSP) in which the subset of locations to be visited is a random variable. For motivation assume that a company wants to design a tour through *n* customers and wants to minimize the routing cost only. If all the customers have to be visited every day, it is an instance of the classical TSP. Assume however that the same tour has to be used for a longer period and that the set of customers being present with probability 1) and is therefore NP-hard. Furthermore, it is known that there are instances of PTSP for which the optimal TSP tour may be arbitrary bad (Plešinger, 1999, p 289).

### 3.2.1 Formulation of traveling salesman problem

The mathematical formulation of the basic circular task is given a final set of locations and distances, consumption of time or cost rate for each connection pair of these places. We are looking for a sequence of points in which each point appears exactly once and the total valuation of each connection in this sequence is minimal (Získal, Havlíček, 2003, p 66).

Denote the selected sequence positions m indices $i_1$, $i_2$, …, $i_m$ we can calculate the value of this combination as a sum of rates (distance)

$$\sum_{k=1}^{m-1} c_{ik,ik+1} + c_{im,il} \text{(Získal, Havlíček, 2003, p 66).}$$

The requirement that each point in the selected route appeared only once, cannot be understood so that each point passes only once, it does not always exist a unique connection between each pair of seats and must be included in the route turns and end points (Získal, Havlíček, 2003, p 66).

### 3.2.2 Tucker formulation of the traveling salesman problem

Business travelers are supposed to visit *n* points. The distance between the *i*-th and *j*-th place mark symbol $d_{ij}$. The total length of the circular path which is minimized can be expressed as

$$z = \sum_{i=1}^{n} \sum_{j=1}^{n} c_{ij} x_{ij} \rightarrow \text{MIN}$$

where $x_{ij}$ is the number of journeys from place *i* to place and *j* (Získal, Havlíček, 2003, p 66).

Since the round-trip business travelers visit each site once must pay conditions

$$\sum_{j=1}^{n} x_{ij} = 1, \text{j} = 1,2, \dots, \text{n}$$

$$\sum_{i=1}^{n} x_{ij} = 1, \text{i} = 1,2, \dots, \text{n}$$

Constraints *n* not enough to the exact formulation of the problem, since it is possible to also fulfill so that each site ordered after several separate circuits to exclude the possibility of other circuits, formulated Tucker further restrictions:

$$u_i - u_j + nx_{ij} \leq n - 1, \ (i \neq j, \ i, j = 1,2, \dots, n)$$

where $u_i$ is the unknown real number assigned place *i* and

$u_j$ is an unknown real number assigned to location *j* (Získal, Havlíček, 2003, p 66).

Traveling salesman problem is from a mathematical point of view the so-called NP-complete problems, for which no efficient algorithm to find the exact mathematical optimum. It is due to the fact that the number of restrictive conditions in the mathematical model of this role is growing very rapidly (exponentially) with a growing number of places, so any method of calculation time increases with best as quickly and already for medium sized jobs would be incomparably greater. Fortunately, there are many approximation methods, the solution can be regarded as economic optimum (Šubrt et al., 2007, p 37).

When choosing the appropriate methods should be aware of the type of traveling salesman problem is. The most important of these tasks include classification the single-circuit and multi-circuit. For some methods it is also essential that rate matrix is symmetric or not. Problems can arise even for tasks with incomplete network of paths or if some links may not be used (Šubrt et al., 2007, p 37).

### 3.2.3 Manual solutions

For circular single-traveling salesman problem algorithms we show two methods: Vogel method which is also applicable to other distribution tasks and methods nearest neighbor, which is perhaps the simplest method for solving traveling salesman problem. Furthermore, we introduce the method suitable for Mayer multi-circuit traveling salesman problem with symmetric matrix rates and limited capacity of vehicles (Šubrt et al., 2007, p 37).

#### 3.2.3.1 Vogel approximation method

Vogel approximation method (VAM) gives a solution close to optimum; therefore, belongs to the most approximation methods. It is based on filling boxes not only by the most economical rates, but also takes into account differences between good rates in the table rows. This ensures the filling convenient connections throughout the calculation evenly (Kosková, 2006, p 10).

Now we will find the procedure to calculate Vogel classical approximation methods used in solving one-step transport tasks. After subsequent explanations classic VAM describes the differences in the use of the traveling salesman problem.

**The calculation algorithm VAM**

1. In each row (row and column) of the table calculate the difference between two best rates.

2. In line with the largest difference we determine the field with the best rate and it will possess the maximum possible amount, after the capacity contractor shall delete the row and column differential count it, satisfaction at the consumer's request excludes the column and line differential count it.

3. Repeat the process at a reduced table to run out of capacity contractors and satisfy the requirements of all consumers (Kosková, 2006, p 10).

Now the only differences are in the calculation of single-stage transport role and the traveling salesman problem.

Notably, the traveling salesman problem does not need to be considered the quantity of goods transported, so before starting the calculation of the table we will only write the rate in the table and during algorithm vacant cells only indicate (underline), which means that the concentration corresponding to these cells are marshaled (added) to the designed route traveling salesman problem route. Other difference is in the occupation scratch out cells. Deleting both the row and the column, in which the filling cell is starting (traveling salesman goes into each from *i* place only once), but in addition it is necessary to delete one other cell, that the currently occupied cell, and possibly even a few previously occupied, which would close circle which passes through all points. After this it is necessary scratch out recalculate row and column difference (Šubrt et al., 2007, p 37).

#### 3.2.3.2 Nearest neighbor method

The principle of this method consists in the fact that we choose a starting point, it is we go to the place in which there is the most advantageous concentration of the starting point, then in another of those places where we have not been yet, which is most advantageous concentration from where we find ourselves, etc. After passing all the places we come back to the default (Šubrt et al., 2007, p 38).

We describe how such a calculation is made in the table (matrix) rates. Mainly we delete the column for the starting point (this point does not go far; we will go back there in the end). The line corresponding to the starting point we find the cell with the minimum (best) rate and denote (will possess) it, i.e., the connection will be included in the resulting circuit route. Hereby connections we are moved to a location which corresponds to the column in which this cell is located. This column we delete (at this point we are not coming back again). In the row that corresponds to this point we extract from cells not scratch out columns again here with the best rate and the process repeat until all the columns scratch out (i.e. until we visited all places). The row in which we find ourselves in the end we will possess cell in column, which corresponds to the starting point (Šubrt et al., 2007, p 38).

Gradually all the places we choose as the default and for each we find that procedure, circuit route. If the task has asymmetrical rates perform the each site also route search "backwards", i.e. either scratch out lines and looking minimum rates in the columns or the original procedure applied to the transposed matrix. From all of the found routes we choose the best (with the smallest sum of rates) (Šubrt et al., 2007, p 38).

## 3.3 Vehicle routing problem

The most common reason why it is necessary traveling salesman problem divided into several areas, are capacity constraints. Capacity of a vehicle is often insufficient to meet the requirements of all the places on the amount of material, window stacking there / here need to get a ride (Šubrt a kolektiv, 2011, p 108).

We assume that all vehicles are the same, have the same capacity which is less than the total volume requirements. It is therefore necessary to schedule several areas (one for each vehicle) so that each began and ended at a central location, the sum capacity (requirements) of all devolved places that are present, must not be greater than the capacity of a vehicle, and each sub-central location must lie just on one circuit (in each place must not central some vehicle to go, but it is useless to go there more vehicles (Šubrt a kolektiv, 2011, p 108).

### 3.3.1 Mayer method

This method is suitable for applications with a complete multi-circuit network of roads and with limited capacity. This is an approximate method adopted by the team Transport Research Institute under the direction of Ing. Mayer. Its suitable for assembly cartage respectively plans for a shorter period a few days (Získal, Havlíček, 2003, p 68).

The solution procedure is based on a symmetric matrix of distances in miles between places included in the solution. Individual seats are in the matrix prepared in sequence by the distance from the central collection point. The farthest place in the matrix referred to as the first, central place last. The solution is carried out in two steps (Získal, Havlíček, 2003, p 68).

First step: Select locations for each circular route distance matrix starts from the farthest place that will be included in the first orbital route so the highest situated place in the matrix with the specified transported amount. The selected item is already assigned to another, which is available to the smallest distance. This is usually the point at which the sequence positions in the array as follows considering the previous direction from the already selected points and the center (Získal, Havlíček, 2003, p 68).

After the assignment of additional space in the circular route there is need for sum shipping requirements for seats and compare it with a transport capacity considered vehicle. If the capacity of a vehicle is not busy, assigned by the smallest distance, and additional space will again compared to the sum of transport capacity requirements of the vehicle in the same manner, continuing until end capacity of the vehicle (Získal, Havlíček, 2003, p 68).

Venues for the next round start again the extreme route transport demand again, which has not yet been assigned. The procedure is the same as in the previous case (Získal, Havlíček, 2003, p 68).

Second Step: In the second step there are sort of sites in individual routes. Places selected in each circular route are sorted according to the minimum length of individual links and routes in total. Routes are adjusted to reflect intuitive decision making and knowledge of man. For this it is necessary to know the distribution and characteristics of road networks. It is also advisable to consider the volume of transported individual sections of the material (Získal, Havlíček, 2003, p 68).

### 3.3.2 Habr method of absolute expediency (MAV)

Habr approximation method of solving the traveling salesman problem creates that of all the possible connections between locations and selects circuit classifies such operations, which are the most advantageous in terms of the whole considered transport network. This provides a global view of Habr frequency (Získal, Havlíček, 2003, p 70).

The procedure assumes that the calculated frequencies and all possible connections between locations are selected and the circle it ranks first connection two sites corresponding to the best frequency. Then it looks for favorable frequency for related links and relevant section shall be included in the circuit thus continues until the circuit closes. To improve and speed up the process, it needs to be not operating with frequencies as the overall profitability of individual characteristics sections of the network, but with the spaced frequencies (Získal, Havlíček, 2003, p 71).

**Algorithm methods MAV**

1. For base tables draw distances with analytical partial table row gap rates.
2. In sub-tables are found row minimum to highlight it.
3. For creating circle be selected those connections for which the row minima concentrated in a particular column partial tables.
4. If there are in a given transport network absolutely advantageous connection, it is found all connections absolutely disadvantageous. Connect with maximum number of minimum in the column then confrontation with links absolutely unfavorable. If some of these connections is a disadvantage in relation to a connection that is

completely disadvantageous considering the other so as to be absolutely competitive.

5. From the absolutely advantageous connections that are independent of each other, creating a first sections sightseeing services.
6. The inclusion of a link is reduced initial sub-table, so that all the values corresponding to these connections are omitted from consideration (in the table the corresponding number of delete). Furthermore, the launch of all other considerations involved, which could cause premature closure of the circuit (e.g. combining opposite directions).
7. In the remaining sub-tables again seek connection absolutely advantageous respective disadvantageous. The procedure is repeated until the circuit is closed (Získal, Havlíček, 2003, p 71).

## 3.4 Other methods for traveling salesman problem

### 3.4.1 Savings methods (Clark, Wright)

Procedure:

1. We derive a matrix of numbers expedient

$s_{ij} = d_{i1} + d_{1j} - d_{ij}$, for i, j = 1,2, ..., n, where D = $\{d_{ij}\}$ is the matrix shortest distance between network nodes.

2. Sort numbers $s_{ij}$ in descending order.
3. According to figures collated $s_{ij}$ gradually associate node i with node j so that a final cycle (numbers $s_{ij}$, that the merger would create a node i and j cycles, skip).

The number of operations, including sorting order is $n^2 \log(n)$ (Pelikán, 1992, p 40).

#### 3.4.2 Insertion method

Procedure:

1. Select the default node (denoted by the number 1).
2. Find the node with the next node 1 ($c_{1s}$ = min {$c_{1j}$}) and create a default cycle c: 1-s-1.
3. Find the node k that is closest nodes already included in the cycle c.
4. Find an edge (i, j) lying on C, for which the minimum $c_{ik} + c_{kj} – c_{ij}$ and put the nodes between nodes i and j in cycle c.
5. Repeat point 3 and 4 until the cycle c contains all nodes graph (Pelikán 1992, p 40).

#### 3.4.3 Dantzig, Fulkerson and Johnson method

Converts traveling salesman problem to the problem of the role of integer programming solved with the simplex method. The procedure is quite complicated. In fact, it uses an assignment problem with a maximum degeneration (Získal, Havlíček, 2003, p 67).

#### 3.4.4 Croes method

It solves the problem of gradual improvement of the initial solution of certain changes in the order as long as possible. Any solution, however, generally is not optimal. To find the optimum is used considerably more complex procedure (Získal, Havlíček, 2003, p 67).

#### 3.4.5 Little method

Is based on branch and bound method (Branch and Bound) set all feasible solutions (cycles) are divided on a shrinking subset for each subset we calculate boundary minimum achievable cycle length. The procedure ends when the solution is found with the smallest value for the lowest connection straight line. The method is suitable for the determination of orbital route at unlimited capacity vehicles (Získal, Havlíček, 2003, p 67).

### 3.4.6 Barták with team

Combinatorial Method for the different types of round task and for testing of the solution found using the Hungarian method (Získal, Havlíček, 2003, p 68).

## 3.5 Computer solutions

In the Czech University of Life Sciences there is a QSB program available, which is can be solved by the only traveling salesman problem. We use the main menu option 4, which is common to the assignment problem. Therefore, we must when entering the problem in question (the second in line to the home screen), if we want to solve the assignment (assignment - (1)) or circular (traveling salesman - (2)) the problem answers option number 2. Furthermore remark that the second dimension of the matrix rates (number of tasks) is not necessary to enter (you can only confirm pressing "Enter") program automatically assumes a square matrix (query assignment is due a task which may be unbalanced, i.e. a rectangular array of rates). If use it when entering the matrix of rates fixed format does not affect how (and whether at all) are given on the diagonal elements. Otherwise, the operation in solving QSB traveling salesman problem is standard. As a solution, the program first shows a table where each point is the place where the route continues straight final concentration and, on the next screen, then this is a circular route shown in full (Šubrt et al., 2007, p 38).

# 4 Characteristics of the company and description of the problem

## 4.1 Supply chain management, Company Polet Wunik International

Polet Wunik International is Taiwanese company heading in Taipei.

**2006 -** Polet Wunik International Ltd. was established in Taipei, Taiwan. The office was set up in a business center with 2 staffs and 2 desks, located in Xiemen, Taipei. Polet Wunik International Ltd. mainly provides buying service and product inspection service for Russian client.

**2007 -** Male underwear distribution department established. The company started with an online shop, named Qpub, distributed male new fashionable underwear in Taiwan market. Later on, the e-shop name was changed to Myqpbd.

**2008 -** Male underwear distribution department closed. Even though within 1 year of operation, Myqpbd ranked as Taiwan's 2nd biggest online male underwear shop and owns a showroom in the famous fashion district of Taipei, for putting a focus on its resources and operation domain, the company decided to close such a business unit.

**2010 -** Launch Polet Wunik International Supply Services (PWISS) supply services established. PWISS services provide a more complete package in terms of supply chain services.

- To help small & medium sized companies globally obtain competitive advantages through supply services we provide.
- To help circulate and utilize resources more efficiently in a global operation perspective.
- To make fundamental changes to the society by providing advanced training to its staff.

Established by a team in its 30s & 40s, the company is very enthusiastic about bringing a positive change to the world (http://www.pwiss.net/).

The company wants to bring a unique business model to its business, emphasizing partnership, creativity and shared partner growth. Skillfully implemented, these values promote economic activities which do not only generate more resources in order to recruit more staff locally and internationally within the channel network but also help circulate and utilize earth's resources more efficiently (http://www.pwiss.net/).

PWISS's founder and current CEO, Mr. Yuan-ho Wu, started this company with an ambition to deliver his contribution to the world by providing more opportunities for global employees to grow into professionals. He wanted to provide chances to form positive thinking habits and the right attitude to embrace challenges in life. He also looks into every employee, discovers and encourages employees to play on its strength (http://www.pwiss.net/).

**International Sales Office** (ISO) is an advanced partnership format PWISS offers in comparing to sales agent or manufacturers' export agent or import agent or import commission house or commission merchant (http://www.pwiss.net/).

The blooming Asian economy especially the emerging Great China region, including China, Taiwan, Hong Kong, and Macau, lays opportunities for companies around the world. Being experienced channel marketers locally, The Polet Wunik International Sales Office (PWISO) service helps clients to develop such market and seize the market opportunity with the need to input a very limited amount of resources (http://www.pwiss.net/).

In general, the ISO service can bring channels for client's products right after evaluation and research here in China and Taiwan. PWISS provides assistance to the channel members in order to maximize performance when selling to end users (http://www.pwiss.net/).

Currently the company has two different segments in PWISO service:

- **Consumer Product:** products intended to be consumed by end-user in retail channel, and

- **Industrial Product:** industrial products that are intended to be used as parts or material (http://www.pwiss.net/).

International Purchasing Office (IPO) or International Buying Office or International Procurement Center is a global sourcing strategy adapted by multinational companies. IPO is an advanced partnership format compared to purchase agent or buy agent (http://www.pwiss.net/).

As a 3rd party IPO, PWISS takes the essential concepts and tools those big companies can afford and uses them to help small and medium enterprises (SMEs) around the world with limited resources to implement such business strategies. Therefore helping the company is to gain competitiveness from global sourcing, especially in the region of China and Taiwan (http://www.pwiss.net/).

PWISS has many customers around the world, but this diploma thesis is focus on two Czech customers which PWISS cooperate with. Both cases are introduced in chapter 5.

## 4.2 Client BUSHMANN

BUSHMAN outdoor clothing and equipment is designed for men and women who love freedom and travel, discovery and adventure. Its designs are not only guided by common sense but also by instinct and driven by a strong respect for nature (http://www.bushmanwear.eu/).

The company design and manufacture all its products themselves to ensure reliability and practicality, and above all the company are designed to dependably protect clients on its travels. The company uses natural materials wherever possible, such as cotton, wool, flax, bamboo, leather, etc. By using modern manufacturing and treatment techniques the company has been able to achieve unsurpassed product durability (http://www.bushmanwear.eu/).

It is important for them to minimize the effect of its products on the environment. The company does not want its products to end up in land-fills. All its clothing and equipment are made of natural materials that can be disposed of in an environmentally responsible way or simply recycled (http://www.bushmanwear.eu/).

The company has focused on the development and manufacture of outdoor clothing since 1997. Because the company love adventure travel ourselves, the company know what people need on its travels. Since the company started its business, the company has created over thirty unique collections of clothing and accessories, which in turn have ushered in the Bushman style of dressing. Its clothes allow clients to go anywhere - in the mountains, forest or desert. Its clothes will keep clients comfortable and stylish anywhere in the wilderness or in civilization, even after washing (http://www.bushmanwear.eu/).

Every year the company create two new collections of clothes and accessories; one for each of the summer and winter seasons. The company is constantly striving to innovate and improve its products in order to meet the requirements and demands of today’s needs. Nevertheless, its collections are a perfect blend of functionality and reliability that has endured the test of time. The company does not make clothes that live for one fashion season, but instead the company tries to forge its own path (http://www.bushmanwear.eu/).

Sometimes it happens that the company does not have enough information to make the right life decisions or choose the right direction. When this happens, clients have to rely on clients own instincts. It is one of the few moments when the laws of nature come sharply into focus. If Bushman products help clients to succeed in these situations, the company would have achieved its goal (http://www.bushmanwear.eu/).

### 4.2.1 Business between PWISS and BUSHMANN

The BUSHMANN Client would like to enter the Taiwanese market and company PWISS Company will provide customers who would buy its goods. The BUSHMANN Client wants to sell its products, which is clothes. The Client will customize its goods to Taiwanese demand. For example there is no sense to sell winter clothes in Taiwan because Taiwanese winter is different than in the Czech Republic. The contract is going to be from Czech Republic to nine cities in Taiwan, where BUSHMANN is going to sell its products.

In this diploma thesis we are going to optimize the transportations routes between Czech Republic and Taiwanese cities.

For optimizing the routes, we will use 2 methods, the nearest neighbor method and Vogel approximation method. The complete solutions are in chapter 5.

## 4.3 Client Šumavský pramen

ŠUMAVSKÝ PRAMEN Inc., founded in 2000, is a company with a long tradition in the field of production and bottling of excellent spring water ŠUMAVSKÝ PRAMEN into barrels and its sale and distribution throughout the country. Also engaged in the sale of the latest Aqua mat (water dispensers), which will provide clients with a convenient way to follow its drinking regime (http://www.sumavskypramen.cz/).

Its goal is to offer a professional and high-quality products and service to all our customers, which is responsible for its professional team and a wide network of distributors in all regions of the Czech Republic and the Slovak Republic (http://www.sumavskypramen.cz/).

The slogan of the company is ŠUMAVSKÝ PRAMEN HARMONY - HEALTH - MOVE, so it's also been involved in supporting the athletes and artists (http://www.sumavskypramen.cz/).

### 4.3.1 Business between PWISS and ŠUMAVSKÝ PRAMEN

Šumavský pramen decided to cooperate with PWISS. The company wants to reduce costs and because of that, the company will accept PWISS services. PWISS is going to find new suppliers from the Taiwanese or Chinese markets of barrel machines (aqua mats). PWISS will contact companies who provide those barrel machines and try to find the best deal for Šumavský pramen. This part also includes logistics cost which is the part of this diploma thesis.

Chapter 5 presents the solution to logistic from Taiwan to Šumavský pramen clients in Czech Republic. In the beginning the contract will consist of just some small amount of containers because the Šumavský pramen client wants first try to and see if the business with PWISS is good and later it is planned to have higher amount of containers which means more difficult logistic system. In this case in chapter 5 there are 2 solutions, first for the smaller amounts of containers and second for the higher amounts of containers. In the first solution 2 methods are going to be used, the nearest neighbor method and Vogel approximation method, and for the second solution we will use the Mayer method.

# 5 Problem solution and analysis

In this diploma thesis we will present the results of logistics optimization for both cases just in Czech Republic and in Taiwan. We will briefly introduce the solution before we present the optimization routes.

The goods for the second client (Šumavský pramen) are coming from China.

There are 3 possibilities to deliver cargo from China to Czech:

1. By sea – vessel line from Shenzen, China to Frankfurt, Germany and then by truck to the Czech Republic
2. By air – first by truck to Hong Kong and then directly to Prague
3. By train – from Shenzen to ChungChing, China, to Germany and then by truck to the Czech Republic

The result is, of course, to use the sea shipment due to the quantity being too big and too expensive to take air cargo and the new route for train is new, the price is still too expensive while too much uncertainty now for custom clearances around the boarders.

a) By Air: Since the volume of water dispenser is big and it is heavy, it is not suitable to ship it by air. Although it is the fastest way to deliver goods, the freight cost is too huge.

b) By Rail: The trains may be stopped at each transit point due to customs check (longer time). There are many check points needed to be followed up and it is not easy to control well the status of shipment.

c) By Sea: Although it is the cheapest method for transportation, it takes a longer time to deliver. It is mandatory to pay higher attention on the process when goods are unloaded from Hamburg and then transited to Prague by truck.

| From NingBo, China to Prague, Czech Republic | | | |
|---|---|---|---|
| Method | By Air | By Rail | By Sea |
| Freight cost | US$35,845.00 | US$8,333.00 | US$2,350.00 |
| Transit time | 5 days | 25 days | 40 days |
| Transit route | NingBo, China > Shanghai, China > Prague, Czech | NingBo, China > XinJiang, China > Vladivostik, Russia > Hamburg, Germany > Prague, Czech | NingBo, China > Hamburg, Germany > Prague, Czech |
| Distance | 8625.48 km | 4133.24 km | 9135.78km |

**Table 5-1Costs for transportation from China to Europe**

The main suppliers warehouse is located NingBo instead of Shenzhen.

This is just for information; the delivery from China to Czech Republic depends on the price and also how fast the company needs the goods. We will just solve the traveling salesman problem from the distribution warehouse to local partners.

## 5.1 Optimization routes for client 2, BUSHMANN

For this case we are going to use two methods. The first one is the nearest neighbor and the second one is the Vogel approximation method. In the end we will compare both results and the best result will be introduced to the company. We have to start the route in Taoyuan because there is the main point for incoming containers. In both the methods we have to customize the results for the right direction, which means that the route has to start in Taoyuan.

### 5.1.1 Nearest neighbor method

We choose to use this method to optimize the routes in the Czech Republic. We will demonstrate how to calculate this method.

#### 5.1.1.1 Chiayi

Chiayi as the first city, we will explain how to apply the nearest neighbor method. Here we can see the original table with distances between the cities.

| | Chiayi | Hsinchu | Hualien | Kaohsiung | Keelung | Taichung | Tainan | Taipei | Taoyuan |
|---|---|---|---|---|---|---|---|---|---|
| **Chiayi** | x | 178 | 251 | 140 | 270 | 144 | 53 | 256 | 225 |
| **Hsinchu** | 178 | x | 254 | 316 | 100 | 116 | 218 | 85 | 56 |
| **Hualien** | 251 | 254 | x | 261 | 177 | 353 | 292 | 176 | 208 |
| **Kaohsiung** | 140 | 316 | 261 | x | 407 | 282 | 110 | 394 | 362 |
| **Keelung** | 270 | 100 | 177 | 407 | X | 205 | 311 | 21 | 55 |
| **Taichung** | 144 | 116 | 353 | 282 | 205 | x | 185 | 189 | 159 |
| **Tainan** | 53 | 218 | 292 | 110 | 311 | 185 | x | 296 | 265 |
| **Taipei** | 256 | 85 | 176 | 394 | 21 | 189 | 296 | x | 40 |
| **Taoyuan** | 225 | 56 | 208 | 362 | 55 | 159 | 265 | 40 | x |

Table 5-2 Nearest neighbor method, the main table

First we delete the field (column) of the city of Chiayi. We find the minimum distance from the city of departure, in our case, Tainan.

| | Chiayi | Hsinchu | Hualien | Kaohsiung | Keelung | Taichung | Tainan | Taipei | Taoyuan |
|---|---|---|---|---|---|---|---|---|---|
| **Chiayi** | x | 178 | 251 | 140 | 270 | 144 | 53 | 256 | 225 |
| **Hsinchu** | 178 | x | 254 | 316 | 100 | 116 | 218 | 85 | 56 |
| **Hualien** | 251 | 254 | x | 261 | 177 | 353 | 292 | 176 | 208 |
| **Kaohsiung** | 140 | 316 | 261 | x | 407 | 282 | 110 | 394 | 362 |
| **Keelung** | 270 | 100 | 177 | 407 | X | 205 | 311 | 21 | 55 |
| **Taichung** | 144 | 116 | 353 | 282 | 205 | x | 185 | 189 | 159 |
| **Tainan** | 53 | 218 | 292 | 110 | 311 | 185 | x | 296 | 265 |
| **Taipei** | 256 | 85 | 176 | 394 | 21 | 189 | 296 | x | 40 |
| **Taoyuan** | 225 | 56 | 208 | 362 | 55 | 159 | 265 | 40 | x |

**Table 5-3 Nearest neighbor method, Chiayi as the first city I.**

We delete the column Tainan and from row Tainan looking for the closest distance. We will repeat the procedure until the end.

| | Chiayi | Hsinchu | Hualien | Kaohsiung | Keelung | Taichung | Tainan | Taipei | Taoyuan |
|---|---|---|---|---|---|---|---|---|---|
| **Chiayi** | x | 178 | 251 | 140 | 270 | 144 | 53 | 256 | 225 |
| **Hsinchu** | 178 | x | 254 | 316 | 100 | 116 | 218 | 85 | 56 |
| **Hualien** | 251 | 254 | x | 261 | 177 | 353 | 292 | 176 | 208 |
| **Kaohsiung** | 140 | 316 | 261 | x | 407 | 282 | 110 | 394 | 362 |
| **Keelung** | 270 | 100 | 177 | 407 | X | 205 | 311 | 21 | 55 |
| **Taichung** | 144 | 116 | 353 | 282 | 205 | x | 185 | 189 | 159 |
| **Tainan** | 53 | 218 | 292 | 110 | 311 | 185 | x | 296 | 265 |
| **Taipei** | 256 | 85 | 176 | 394 | 21 | 189 | 296 | x | 40 |
| **Taoyuan** | 225 | 56 | 208 | 362 | 55 | 159 | 265 | 40 | x |

**Table 5-4 Nearest neighbor method, Chiayi as the first city II**

In the last line we will highlight the box in the column starting point. After that we provide the final table.

| | Chiayi | Hsinchu | Hualien | Kaohsiung | Keelung | Taichung | Tainan | Taipei | Taoyuan |
|---|---|---|---|---|---|---|---|---|---|
| Chiayi | x | 178 | 251 | 140 | 270 | 144 | 53 | 256 | 225 |
| Hsinchu | 178 | x | 254 | 316 | 100 | 116 | 218 | 85 | 56 |
| Hualien | 251 | 254 | x | 261 | 177 | 353 | 292 | 176 | 208 |
| Kaohsiung | 140 | 316 | 261 | x | 407 | 282 | 110 | 394 | 362 |
| Keelung | 270 | 100 | 177 | 407 | X | 205 | 311 | 21 | 55 |
| Taichung | 144 | 116 | 353 | 282 | 205 | x | 185 | 189 | 159 |
| Tainan | 53 | 218 | 292 | 110 | 311 | 185 | x | 296 | 265 |
| Taipei | 256 | 85 | 176 | 394 | 21 | 189 | 296 | x | 40 |
| Taoyuan | 225 | 56 | 208 | 362 | 55 | 159 | 265 | 40 | x |

Table 5-5 Nearest neighbor method, Chiayi as the first city, result

The resulting circuit Chiayi as the initial city:

Chiayi – Tainan – Kaohsiung – Hualien – Taipei – Keelung – Taoyuan – Hsinchu – Taichung - Chiayi

53 + 110 + 261 + 176 + 21 + 55 + 56 + 116 + 144 = 992 km

In this way we calculate all the possibilities with each other starting point. Now just take a look at the results.

#### 5.1.1.2 Hsinchu

| | Chiayi | Hsinchu | Hualien | Kaohsiung | Keelung | Taichung | Tainan | Taipei | Taoyuan |
|---|---|---|---|---|---|---|---|---|---|
| Chiayi | x | 178 | 251 | 140 | 270 | 144 | 53 | 256 | 225 |
| Hsinchu | 178 | x | 254 | 316 | 100 | 116 | 218 | 85 | 56 |
| Hualien | 251 | 254 | x | 261 | 177 | 353 | 292 | 176 | 208 |
| Kaohsiung | 140 | 316 | 261 | x | 407 | 282 | 110 | 394 | 362 |
| Keelung | 270 | 100 | 177 | 407 | X | 205 | 311 | 21 | 55 |
| Taichung | 144 | 116 | 353 | 282 | 205 | x | 185 | 189 | 159 |
| Tainan | 53 | 218 | 292 | 110 | 311 | 185 | x | 296 | 265 |
| Taipei | 256 | 85 | 176 | 394 | 21 | 189 | 296 | x | 40 |
| Taoyuan | 225 | 56 | 208 | 362 | 55 | 159 | 265 | 40 | x |

Table 5-6 Nearest neighbor method, Hsinchu as the first city, result

Hsinchu – Taoyuan – Taipei – Keelung – Hualien – Chiayi – Tainan – Kaohsiung – Taichung – Hsinchu

56 + 40 + 21 + 177 + 251 + 53 + 110 + 282 + 116 = 1106 km

### 5.1.1.3 Hualien

| | Chiayi | Hsinchu | Hualien | Kaohsiung | Keelung | Taichung | Tainan | Taipei | Taoyuan |
|---|---|---|---|---|---|---|---|---|---|
| **Chiayi** | x | 178 | 251 | 140 | 270 | 144 | 53 | 256 | 225 |
| **Hsinchu** | 178 | x | 254 | 316 | 100 | 116 | 218 | 85 | 56 |
| **Hualien** | 251 | 254 | x | 261 | 177 | 353 | 292 | 176 | 208 |
| **Kaohsiung** | 140 | 316 | 261 | x | 407 | 282 | 110 | 394 | 362 |
| **Keelung** | 270 | 100 | 177 | 407 | X | 205 | 311 | 21 | 55 |
| **Taichung** | 144 | 116 | 353 | 282 | 205 | x | 185 | 189 | 159 |
| **Tainan** | 53 | 218 | 292 | 110 | 311 | 185 | x | 296 | 265 |
| **Taipei** | 256 | 85 | 176 | 394 | 21 | 189 | 296 | x | 40 |
| **Taoyuan** | 225 | 56 | 208 | 362 | 55 | 159 | 265 | 40 | x |

Table 5-7 Nearest neighbor method, Hualien as the first city, result

Hualien – Taipei – Keelung – Taoyuan – Hsinchu – Taichung – Chiayi – Tainan – Kaohsiung – Hualien

176 + 21 + 55 + 56 + 116 + 144 + 53 + 110 + 261 = 992 km

### 5.1.1.4 Kaohsiung

| | Chiayi | Hsinchu | Hualien | Kaohsiung | Keelung | Taichung | Tainan | Taipei | Taoyuan |
|---|---|---|---|---|---|---|---|---|---|
| **Chiayi** | x | 178 | 251 | 140 | 270 | 144 | 53 | 256 | 225 |
| **Hsinchu** | 178 | x | 254 | 316 | 100 | 116 | 218 | 85 | 56 |
| **Hualien** | 251 | 254 | x | 261 | 177 | 353 | 292 | 176 | 208 |
| **Kaohsiung** | 140 | 316 | 261 | x | 407 | 282 | 110 | 394 | 362 |
| **Keelung** | 270 | 100 | 177 | 407 | X | 205 | 311 | 21 | 55 |
| **Taichung** | 144 | 116 | 353 | 282 | 205 | x | 185 | 189 | 159 |
| **Tainan** | 53 | 218 | 292 | 110 | 311 | 185 | x | 296 | 265 |
| **Taipei** | 256 | 85 | 176 | 394 | 21 | 189 | 296 | x | 40 |
| **Taoyuan** | 225 | 56 | 208 | 362 | 55 | 159 | 265 | 40 | x |

Table 5-8 Nearest neighbor method, Kaohsiung as the first city, result

Kaohsiung – Tainan – Chiayi – Taichung – Hsinchu – Taoyuan – Taipei – Keelung – Hualien – Kaohsiung

110 + 53 + 144 + 116 + 56 + 40 + 21 + 177 + 261 = 978 km

### 5.1.1.5 Keelung

| | Chiayi | Hsinchu | Hualien | Kaohsiung | Keelung | Taichung | Tainan | Taipei | Taoyuan |
|---|---|---|---|---|---|---|---|---|---|
| **Chiayi** | x | 178 | 251 | 140 | 270 | 144 | 53 | 256 | 225 |
| **Hsinchu** | 178 | x | 254 | 316 | 100 | 116 | 218 | 85 | 56 |
| **Hualien** | 251 | 254 | x | 261 | 177 | 353 | 292 | 176 | 208 |
| **Kaohsiung** | 140 | 316 | 261 | x | 407 | 282 | 110 | 394 | 362 |
| **Keelung** | 270 | 100 | 177 | 407 | X | 205 | 311 | 21 | 55 |
| **Taichung** | 144 | 116 | 353 | 282 | 205 | x | 185 | 189 | 159 |
| **Tainan** | 53 | 218 | 292 | 110 | 311 | 185 | x | 296 | 265 |
| **Taipei** | 256 | 85 | 176 | 394 | 21 | 189 | 296 | x | 40 |
| **Taoyuan** | 225 | 56 | 208 | 362 | 55 | 159 | 265 | 40 | x |

Table 5-9 Nearest neighbor method, Keelung as the first city, result

Keelung – Taipei – Taoyuan – Hsinchu – Taichung – Chiayi – Tainan – Kaohsiung – Hualien – Keelung

21 + 40 + 56 + 116 + 144 + 53 + 110 + 261 + 177 = 978 km

### 5.1.1.6 Taichung

| | Chiayi | Hsinchu | Hualien | Kaohsiung | Keelung | Taichung | Tainan | Taipei | Taoyuan |
|---|---|---|---|---|---|---|---|---|---|
| **Chiayi** | x | 178 | 251 | 140 | 270 | 144 | 53 | 256 | 225 |
| **Hsinchu** | 178 | x | 254 | 316 | 100 | 116 | 218 | 85 | 56 |
| **Hualien** | 251 | 254 | x | 261 | 177 | 353 | 292 | 176 | 208 |
| **Kaohsiung** | 140 | 316 | 261 | x | 407 | 282 | 110 | 394 | 362 |
| **Keelung** | 270 | 100 | 177 | 407 | X | 205 | 311 | 21 | 55 |
| **Taichung** | 144 | 116 | 353 | 282 | 205 | x | 185 | 189 | 159 |
| **Tainan** | 53 | 218 | 292 | 110 | 311 | 185 | x | 296 | 265 |
| **Taipei** | 256 | 85 | 176 | 394 | 21 | 189 | 296 | x | 40 |
| **Taoyuan** | 225 | 56 | 208 | 362 | 55 | 159 | 265 | 40 | x |

Table 5-10 Nearest neighbor method, Taichung as the first city, result

Taichung – Hsinchu – Taoyuan – Taipei – Keelung – Hualien – Chiayi – Tainan – Kaohsiung – Taichung

116 + 56 + 40 + 21 + 177 + 251 + 53 + 110 + 282 = 1106 km

### 5.1.1.7 Tainan

| | Chiayi | Hsinchu | Hualien | Kaohsiung | Keelung | Taichung | Tainan | Taipei | Taoyuan |
|---|---|---|---|---|---|---|---|---|---|
| Chiayi | x | 178 | 251 | 140 | 270 | 144 | 53 | 256 | 225 |
| Hsinchu | 178 | x | 254 | 316 | 100 | 116 | 218 | 85 | 56 |
| Hualien | 251 | 254 | x | 261 | 177 | 353 | 292 | 176 | 208 |
| Kaohsiung | 140 | 316 | 261 | x | 407 | 282 | 110 | 394 | 362 |
| Keelung | 270 | 100 | 177 | 407 | X | 205 | 311 | 21 | 55 |
| Taichung | 144 | 116 | 353 | 282 | 205 | x | 185 | 189 | 159 |
| Tainan | 53 | 218 | 292 | 110 | 311 | 185 | x | 296 | 265 |
| Taipei | 256 | 85 | 176 | 394 | 21 | 189 | 296 | x | 40 |
| Taoyuan | 225 | 56 | 208 | 362 | 55 | 159 | 265 | 40 | x |

Table 5-11 Nearest neighbor method, Tainan as the first city, result

Tainan – Chiayi – Kaohsiung – Hualien – Taipei – Keelung – Taoyuan – Hsinchu – Taichung – Tainan

53 + 140 + 261 + 176 + 21 + 55 + 56 + 116 + 185 = 1063 km

### 5.1.1.8 Taipei

| | Chiayi | Hsinchu | Hualien | Kaohsiung | Keelung | Taichung | Tainan | Taipei | Taoyuan |
|---|---|---|---|---|---|---|---|---|---|
| Chiayi | x | 178 | 251 | 140 | 270 | 144 | 53 | 256 | 225 |
| Hsinchu | 178 | x | 254 | 316 | 100 | 116 | 218 | 85 | 56 |
| Hualien | 251 | 254 | x | 261 | 177 | 353 | 292 | 176 | 208 |
| Kaohsiung | 140 | 316 | 261 | x | 407 | 282 | 110 | 394 | 362 |
| Keelung | 270 | 100 | 177 | 407 | X | 205 | 311 | 21 | 55 |
| Taichung | 144 | 116 | 353 | 282 | 205 | x | 185 | 189 | 159 |
| Tainan | 53 | 218 | 292 | 110 | 311 | 185 | x | 296 | 265 |
| Taipei | 256 | 85 | 176 | 394 | 21 | 189 | 296 | x | 40 |
| Taoyuan | 225 | 56 | 208 | 362 | 55 | 159 | 265 | 40 | x |

Table 5-12 Nearest neighbor method, Taipei as the first city, result

Taipei – Keelung – Taoyuan – Hsinchu – Taichung – Chiayi – Tainan – Kaohsiung – Hualien – Taipei

21 + 55 + 56 + 116 + 144 + 53 + 110 + 261 + 176 = 992 km

#### 5.1.1.9 Taoyuan

| | Chiayi | Hsinchu | Hualien | Kaohsiung | Keelung | Taichung | Tainan | Taipei | Taoyuan |
|---|---|---|---|---|---|---|---|---|---|
| **Chiayi** | x | 178 | 251 | 140 | 270 | 144 | 53 | 256 | 225 |
| **Hsinchu** | 178 | x | 254 | 316 | 100 | 116 | 218 | 85 | 56 |
| **Hualien** | 251 | 254 | x | 261 | 177 | 353 | 292 | 176 | 208 |
| **Kaohsiung** | 140 | 316 | 261 | x | 407 | 282 | 110 | 394 | 362 |
| **Keelung** | 270 | 100 | 177 | 407 | X | 205 | 311 | 21 | 55 |
| **Taichung** | 144 | 116 | 353 | 282 | 205 | x | 185 | 189 | 159 |
| **Tainan** | 53 | 218 | 292 | 110 | 311 | 185 | x | 296 | 265 |
| **Taipei** | 256 | 85 | 176 | 394 | 21 | 189 | 296 | x | 40 |
| **Taoyuan** | 225 | 56 | 208 | 362 | 55 | 159 | 265 | 40 | x |

Table 5-13 Nearest neighbor method, Taoyuan as the first city, result

Taoyuan – Taipei – Keelung – Hsinchu – Taichung – Chiayi – Tainan – Kaohsiung – Hualien – Taoyuan

40 + 21 + 100 + 116 + 144 + 53 + 110 + 261 + 208 = 1053 km

**The result:**

| First city | Circularize connected | Length |
|---|---|---|
| **Chiayi** | Chia – Tainan – Kaohsiung – Hualien – Taipei – Keelung – Taoyuan – Hsinchu – Taichung – Chiayi | 992 |
| **Hsinchu** | Hsinchu – Taoyuan – Taipei – Keelung – Hualien – Chiayi – Tainan – Kaohsiung – Taichung – Hsinchu | 1106 |
| **Hualien** | Hualien – Taipei – Keelung – Taoyuan – Hsinchu – Taichung – Chiayi – Tainan – Kaohsiung – Hualien | 992 |
| **Kaohsiung** | Kaohsiung – Tainan – Chiayi – Taichung – Hsinchu – Taoyuan – Taipei – Keelung – Hualien – Kaohsiung | 978 |
| **Keelung** | Keelung – Taipei – Taoyuan – Hsinchu – Taichung – Chiayi – Tainan – Kaohsiung – Hualien – Keelung | 978 |
| **Taichung** | Taichung – Hsinchu – Taoyuan – Taipei – Keelung – Hualien – Chiayi – Tainan – Kaohsiung – Taichung | 1106 |
| **Tainan** | Tainan – Chiayi – Kaohsiung – Hualien – Taipei – Keelung – Taoyuan – Hsinchu – Taichung – Tainan | 1063 |
| **Taipei** | Taipei – Keelung – Taoyuan – Hsinchu – Taichung – Chiayi – Tainan – Kaohsiung – Hualien – Taipei | 992 |
| **Taoyuan** | Taoyuan – Taipei – Keelung – Hsinchu – Taichung – Chiayi – Tainan – Kaohsiung – Hualien – Taoyuan | 1053 |

Table 5-14 The result of nearest neighbor method

As we can see in the table we have 2 of the best results, but we will change the route to start in Taoyuan.

1. Taoyuan – Taipei – Keelung – Hualien – Kaohsiung – Tainan – Chiayi – Taichung – Hsinchu – Taoyuan
2. Taoyuan – Hsinchu – Taichung – Chiayi – Tainan – Kaohsiung – Hualien - Keelung – Taipei – Taoyuan

As we can see, we have the same result; the routes have the opposite direction. So our best optimization route is:

Taoyuan – Taipei – Keelung – Hualien – Kaohsiung – Tainan – Chiayi – Taichung – Hsinchu – Taoyuan = 978 km.

### 5.1.2 Vogel approximation method

For each of them we calculate the difference between the two lowest rates. We select the largest difference and mark the box with the lowest rate in the row. We cross out the row and column box. Exclude passing through this route, which would prematurely closed the circuit.

| | Chia. | Hsin. | Hua. | Kao. | Kee. | Taichung | Tainan | Taipei | Taoyuan | Dif. |
|---|---|---|---|---|---|---|---|---|---|---|
| Chiayi | x | 178 | 251 | 140 | 270 | 144 | 53 | 256 | 225 | 87 |
| Hsinchu | 178 | x | 254 | 316 | 100 | 116 | 218 | 85 | 56 | 29 |
| Hualien | 251 | 254 | x | 261 | 177 | 353 | 292 | 176 | 208 | 1 |
| Kaohsiung | 140 | 316 | 261 | x | 407 | 282 | 110 | 394 | 362 | 30 |
| Keelung | 270 | 100 | 177 | 407 | x | 205 | 311 | 21 | 55 | 34 |
| Taichung | 144 | 116 | 353 | 282 | 205 | X | 185 | 189 | 159 | 28 |
| Tainan | 53 | 218 | 292 | 110 | 311 | 185 | x | 296 | 265 | 57 |
| Taipei | 256 | 85 | 176 | 394 | 21 | 189 | 296 | x | 40 | 19 |
| Taoyuan | 225 | 56 | 208 | 362 | 55 | 159 | 265 | 40 | x | 15 |
| Difference | 87 | 29 | 1 | 30 | 34 | 28 | 57 | 19 | 15 | |

Table 5-15 Vogel approximation method, first step

We repeat the process with the modified table.

| | Chia. | Hsin. | Hua. | Kao. | Kee. | Taichung | Tainan | Taipei | Taoyuan | Dif. | Dif. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Chiayi | x | 178 | 251 | 140 | 270 | 144 | 53 | 256 | 225 | 87 | |
| Hsinchu | 178 | x | 254 | 316 | 100 | 116 | 218 | 85 | 56 | 29 | 29 |
| Hualien | 251 | 254 | x | 261 | 177 | 353 | 292 | 176 | 208 | 1 | 1 |
| Kaohsiung | 140 | 316 | 261 | x | 407 | 282 | 110 | 394 | 362 | 30 | 121 |
| Keelung | 270 | 100 | 177 | 407 | x | 205 | 311 | 21 | 55 | 34 | 34 |
| Taichung | 144 | 116 | 353 | 282 | 205 | X | 185 | 189 | 159 | 28 | 28 |
| Tainan | 53 | 218 | 292 | 110 | 311 | 185 | x | 296 | 265 | 57 | 75 |
| Taipei | 256 | 85 | 176 | 394 | 21 | 189 | 296 | x | 40 | 19 | 19 |
| Taoyuan | 225 | 56 | 208 | 362 | 55 | 159 | 265 | 40 | x | 15 | 15 |
| Difference | 87 | 29 | 1 | 30 | 34 | 28 | 57 | 19 | 15 | | |
| Difference | 4 | 29 | 1 | 151 | 34 | 43 | | 19 | 15 | | |

Table 5-16 Vogel approximation method, second step

The final table:

| | Chiayi | Hsinchu | Hualien | Kaohsiung | Keelung | Taichung | Tainan | Taipei | Taoyuan |
|---|---|---|---|---|---|---|---|---|---|
| **Chiayi** | x | 178 | 251 | 140 | 270 | 144 | 53 | 256 | 225 |
| **Hsinchu** | 178 | x | 254 | 316 | 100 | 116 | 218 | 85 | 56 |
| **Hualien** | 251 | **254** | x | 261 | 177 | 353 | 292 | 176 | 208 |
| **Kaohsiung** | **140** | **316** | 261 | x | 407 | 282 | 110 | 394 | 362 |
| **Keelung** | 270 | 100 | 177 | 407 | X | 205 | 311 | 21 | 55 |
| **Taichung** | 144 | **116** | 353 | 282 | 205 | x | 185 | 189 | 159 |
| **Tainan** | **53** | 218 | 292 | 110 | 311 | 185 | x | 296 | 265 |
| **Taipei** | 256 | 85 | 176 | 394 | 21 | 189 | 296 | x | 40 |
| **Taoyuan** | 225 | 56 | 208 | 362 | **55** | 159 | 265 | 40 | x |

Table 5-17 Vogel approximation Method, final table

Our optimization route is:

Taoyuan – Hsinchu – Taichung – Chiayi – Tainan – Kaohsiung – Hualien – Keelung – Taipei – Taoyuan

56+116+144+53+110+261+177+21+40 = 978 km

### 5.1.3 Result

We used 2 different methods to optimize routes in Taiwan. The results from both methods are the same just the direction is opposite.

It depends on the companies which direction the client prefers. We will introduce to the clients both options and the clients will choose which route they prefer. It should be the direction Taoyuan – Taipei – Keelung – Hualien – Kaohsiung – Tainan – Chiayi – Taichung – Hsinchu – Taoyuan = 978 km because the length of the part of the route, which the track goes fully loaded, is shorter so it means more cost effective and it will optimize workload capacity of the truck.

## 5.2 Optimization routes for client 1, Šumavský pramen

The company Šumavský pramen has the distribution warehouse in Ústí nad Labem and from there the company will distribute the aqua mats into the rest of the Czech Republic. The company has 9 main partners where the company needs to distribute the aqua mats to and the rest will be sent via PPL service.

Its main partners are in Brno, České Budějovice, Hradec Králové, Olomouc, Ostrava, Plzeň, Praha, Šumperk and the distribution warehouse is in Ústí nad Labem. Those places will receive 80% of the total amount and the rest of the orders will be provided via PPL service (clients do not need aqua mats too often, because usually it's a private order).

In the beginning, the Šumavský pramen company plans to make a smaller order from Taiwan and later on the company will make a bigger order so it will need a different logistic system than before.

Firstly, we will optimize the single circulate traveling salesman problem. We will use 2 kinds of optimization methods – the nearest neighbor method and Vogel approximation method. We will introduce the best route to Šumavský Pramen Company.

Secondly, we will optimize the vehicle routing problem (multiple circulate problem). We will use information from Šumavský Pramen about its future plans and for this we will use the Mayer method traveling salesman problem. Also, the results from the optimizing routes will be provided to the company.

### 5.2.1 Nearest neighbor method

Here we can see the original table:

| | Brno | ČB | HK | Olomouc | Ostrava | Plzeň | Praha | Šumperk | ÚnL |
|---|---|---|---|---|---|---|---|---|---|
| Brno | x | 217 | 168 | 78 | 167 | 299 | 206 | 137 | 293 |
| České Budějovice | 217 | x | 254 | 285 | 375 | 134 | 149 | 345 | 236 |
| Hradec Králové | 168 | 254 | x | 141 | 238 | 212 | 117 | 111 | 186 |
| Olomouc | 78 | 285 | 141 | x | 100 | 373 | 280 | 62 | 367 |
| Ostrava | 167 | 375 | 238 | 100 | X | 464 | 370 | 159 | 458 |
| Plzeň | 299 | 134 | 212 | 373 | 464 | x | 98 | 430 | 178 |
| Praha | 206 | 149 | 117 | 280 | 370 | 98 | x | 222 | 88 |
| Šumperk | 137 | 345 | 111 | 62 | 159 | 430 | 222 | x | 299 |
| Ústí nad Labem | 293 | 236 | 186 | 367 | 458 | 178 | 88 | 299 | x |

Table 5-18 Nearest neighbor method

#### 5.2.1.1 Brno

| | Brno | ČB | HK | Olomouc | Ostrava | Plzeň | Praha | Šumperk | ÚnL |
|---|---|---|---|---|---|---|---|---|---|
| Brno | x | 217 | 168 | 78 | 167 | 299 | 206 | 137 | 293 |
| České Budějovice | 217 | x | 254 | 285 | 375 | 134 | 149 | 345 | 236 |
| Hradec Králové | 168 | 254 | x | 141 | 238 | 212 | 117 | 111 | 186 |
| Olomouc | 78 | 285 | 141 | x | 100 | 373 | 280 | 62 | 367 |
| Ostrava | 167 | 375 | 238 | 100 | X | 464 | 370 | 159 | 458 |
| Plzeň | 299 | 134 | 212 | 373 | 464 | x | 98 | 430 | 178 |
| Praha | 206 | 149 | 117 | 280 | 370 | 98 | x | 222 | 88 |
| Šumperk | 137 | 345 | 111 | 62 | 159 | 430 | 222 | x | 299 |
| Ústí nad Labem | 293 | 236 | 186 | 367 | 458 | 178 | 88 | 299 | x |

Table 5-19 Nearest neighbor method, Brno as the first city, result

Brno – Olomouc – Šumperk – Hradec Králové – Praha – Ústí nad Labem – Plzeň – České Budějovice – Ostrava – Brno

78+62+111+117+88+178+134+375+167 = 1310km

### 5.2.1.2 České Budějovice

| | Brno | ČB | HK | Olomouc | Ostrava | Plzeň | Praha | Šumperk | ÚnL |
|---|---|---|---|---|---|---|---|---|---|
| Brno | x | 217 | 168 | 78 | 167 | 299 | 206 | 137 | 293 |
| České Budějovice | 217 | x | 254 | 285 | 375 | 134 | 149 | 345 | 236 |
| Hradec Králové | 168 | 254 | x | 141 | 238 | 212 | 117 | 111 | 186 |
| Olomouc | 78 | 285 | 141 | x | 100 | 373 | 280 | 62 | 367 |
| Ostrava | 167 | 375 | 238 | 100 | X | 464 | 370 | 159 | 458 |
| Plzeň | 299 | 134 | 212 | 373 | 464 | x | 98 | 430 | 178 |
| Praha | 206 | 149 | 117 | 280 | 370 | 98 | x | 222 | 88 |
| Šumperk | 137 | 345 | 111 | 62 | 159 | 430 | 222 | x | 299 |
| Ústí nad Labem | 293 | 236 | 186 | 367 | 458 | 178 | 88 | 299 | x |

**Table 5-20 Nearest neighbor method, České Budějovice as the first city, result**

České Budějovice – Plzeň – Praha – Ústí nad Labem – Hradec Králové – Šumperk – Olomouc – Brno – Ostrava – České Budějovice

134+98+88+186+111+62+78+167+375 = 1299 km

### 5.2.1.3 Hradec Králové

| | Brno | ČB | HK | Olomouc | Ostrava | Plzeň | Praha | Šumperk | ÚnL |
|---|---|---|---|---|---|---|---|---|---|
| Brno | x | 217 | 168 | 78 | 167 | 299 | 206 | 137 | 293 |
| České Budějovice | 217 | x | 254 | 285 | 375 | 134 | 149 | 345 | 236 |
| Hradec Králové | 168 | 254 | x | 141 | 238 | 212 | 117 | 111 | 186 |
| Olomouc | 78 | 285 | 141 | x | 100 | 373 | 280 | 62 | 367 |
| Ostrava | 167 | 375 | 238 | 100 | x | 464 | 370 | 159 | 458 |
| Plzeň | 299 | 134 | 212 | 373 | 464 | x | 98 | 430 | 178 |
| Praha | 206 | 149 | 117 | 280 | 370 | 98 | x | 222 | 88 |
| Šumperk | 137 | 345 | 111 | 62 | 159 | 430 | 222 | x | 299 |
| Ústí nad Labem | 293 | 236 | 186 | 367 | 458 | 178 | 88 | 299 | x |

**Table 5-21 Nearest neighbor method, Hradec Králové as the first city, result**

Hradec Králové – Šumperk – Olomouc – Brno – Ostrava – Praha – Ústí nad Labem – Plzeň – České Budějovice – Hradec Králové

111+62+78+167+370+88+178+134+254 = 1442km

### 5.2.1.4 Olomouc

| | Brno | ČB | HK | Olomouc | Ostrava | Plzeň | Praha | Šumperk | ÚnL |
|---|---|---|---|---|---|---|---|---|---|
| Brno | x | 217 | 168 | 78 | 167 | 299 | 206 | 137 | 293 |
| České Budějovice | 217 | x | 254 | 285 | 375 | 134 | 149 | 345 | 236 |
| Hradec Králové | 168 | 254 | x | 141 | 238 | 212 | 117 | 111 | 186 |
| Olomouc | 78 | 285 | 141 | x | 100 | 373 | 280 | 62 | 367 |
| Ostrava | 167 | 375 | 238 | 100 | X | 464 | 370 | 159 | 458 |
| Plzeň | 299 | 134 | 212 | 373 | 464 | x | 98 | 430 | 178 |
| Praha | 206 | 149 | 117 | 280 | 370 | 98 | x | 222 | 88 |
| Šumperk | 137 | 345 | 111 | 62 | 159 | 430 | 222 | x | 299 |
| Ústí nad Labem | 293 | 236 | 186 | 367 | 458 | 178 | 88 | 299 | x |

Table 5-22 Nearest neighbor method, Olomouc as the first city, result

Olomouc – Šumperk – Hradec Králové – Praha – Ústí nad Labem – Plzeň – České Budějovice – Brno – Ostrava – Olomouc

62+111+117+88+178+134+217+167+100 = 1174km

### 5.2.1.5 Ostrava

| | Brno | ČB | HK | Olomouc | Ostrava | Plzeň | Praha | Šumperk | ÚnL |
|---|---|---|---|---|---|---|---|---|---|
| Brno | x | 217 | 168 | 78 | 167 | 299 | 206 | 137 | 293 |
| České Budějovice | 217 | x | 254 | 285 | 375 | 134 | 149 | 345 | 236 |
| Hradec Králové | 168 | 254 | x | 141 | 238 | 212 | 117 | 111 | 186 |
| Olomouc | 78 | 285 | 141 | x | 100 | 373 | 280 | 62 | 367 |
| Ostrava | 167 | 375 | 238 | 100 | X | 464 | 370 | 159 | 458 |
| Plzeň | 299 | 134 | 212 | 373 | 464 | x | 98 | 430 | 178 |
| Praha | 206 | 149 | 117 | 280 | 370 | 98 | x | 222 | 88 |
| Šumperk | 137 | 345 | 111 | 62 | 159 | 430 | 222 | x | 299 |
| Ústí nad Labem | 293 | 236 | 186 | 367 | 458 | 178 | 88 | 299 | x |

Table 5-23 Nearest neighbor method, Ostrava as the first city, result

Ostrava – Olomouc – Šumperk – Hradec Králové – Praha – Ústí nad Labem – Plzeň – České Budějovice – Brno – Ostrava

100+62+111+117+88+178+134+217+167 = 1174km

### 5.2.1.6 Plzeň

| | Brno | ČB | HK | Olomouc | Ostrava | Plzeň | Praha | Šumperk | ÚnL |
|---|---|---|---|---|---|---|---|---|---|
| Brno | x | 217 | 168 | 78 | 167 | 299 | 206 | 137 | 293 |
| České Budějovice | 217 | x | 254 | 285 | 375 | 134 | 149 | 345 | 236 |
| Hradec Králové | 168 | 254 | x | 141 | 238 | 212 | 117 | 111 | 186 |
| Olomouc | 78 | 285 | 141 | x | 100 | 373 | 280 | 62 | 367 |
| Ostrava | 167 | 375 | 238 | 100 | X | 464 | 370 | 159 | 458 |
| Plzeň | 299 | 134 | 212 | 373 | 464 | x | 98 | 430 | 178 |
| Praha | 206 | 149 | 117 | 280 | 370 | 98 | x | 222 | 88 |
| Šumperk | 137 | 345 | 111 | 62 | 159 | 430 | 222 | x | 299 |
| Ústí nad Labem | 293 | 236 | 186 | 367 | 458 | 178 | 88 | 299 | x |

**Table 5-24 Nearest neighbor method, Plzeň as the first city, result**

Plzeň – Praha – Ústí nad Labem – Hradec Králové – Šumperk - Olomouc – Brno – Ostrava – České Budějovice – Plzeň

98+88+186+111+62+78+167+375+134 = 1299km

### 5.2.1.7 Praha

| | Brno | ČB | HK | Olomouc | Ostrava | Plzeň | Praha | Šumperk | ÚnL |
|---|---|---|---|---|---|---|---|---|---|
| Brno | x | 217 | 168 | 78 | 167 | 299 | 206 | 137 | 293 |
| České Budějovice | 217 | x | 254 | 285 | 375 | 134 | 149 | 345 | 236 |
| Hradec Králové | 168 | 254 | x | 141 | 238 | 212 | 117 | 111 | 186 |
| Olomouc | 78 | 285 | 141 | x | 100 | 373 | 280 | 62 | 367 |
| Ostrava | 167 | 375 | 238 | 100 | X | 464 | 370 | 159 | 458 |
| Plzeň | 299 | 134 | 212 | 373 | 464 | x | 98 | 430 | 178 |
| Praha | 206 | 149 | 117 | 280 | 370 | 98 | x | 222 | 88 |
| Šumperk | 137 | 345 | 111 | 62 | 159 | 430 | 222 | x | 299 |
| Ústí nad Labem | 293 | 236 | 186 | 367 | 458 | 178 | 88 | 299 | x |

**Table 5-25 Nearest neighbor method, Praha as the first city, result**

Praha – Ústí nad Labem – Plzeň – České Budějovice – Brno – Olomouc – Šumperk – Hradec Králové – Ostrava – Praha

88+178+134+217+78+62+111+238+370 = 1468km

### 5.2.1.8 Šumperk

| | Brno | ČB | HK | Olomouc | Ostrava | Plzeň | Praha | Šumperk | ÚnL |
|---|---|---|---|---|---|---|---|---|---|
| Brno | x | 217 | 168 | 78 | 167 | 299 | 206 | 137 | 293 |
| České Budějovice | 217 | x | 254 | 285 | 375 | 134 | 149 | 345 | 236 |
| Hradec Králové | 168 | 254 | x | 141 | 238 | 212 | 117 | 111 | 186 |
| Olomouc | 78 | 285 | 141 | x | 100 | 373 | 280 | 62 | 367 |
| Ostrava | 167 | 375 | 238 | 100 | X | 464 | 370 | 159 | 458 |
| Plzeň | 299 | 134 | 212 | 373 | 464 | x | 98 | 430 | 178 |
| Praha | 206 | 149 | 117 | 280 | 370 | 98 | x | 222 | 88 |
| Šumperk | 137 | 345 | 111 | 62 | 159 | 430 | 222 | x | 299 |
| Ústí nad Labem | 293 | 236 | 186 | 367 | 458 | 178 | 88 | 299 | x |

Table 5-26 Nearest neighbor method, Šumperk as the first city, result

Šumperk – Olomouc – Brno – Ostrava – Hradec Králové – Praha – Ústí nad Labem – Plzeň – České Budějovice – Šumperk

62+78+167+238+117+88+178+134+345 = 1407km

### 5.2.1.9 Ústí nad Labem

| | Brno | ČB | HK | Olomouc | Ostrava | Plzeň | Praha | Šumperk | ÚnL |
|---|---|---|---|---|---|---|---|---|---|
| Brno | x | 217 | 168 | 78 | 167 | 299 | 206 | 137 | 293 |
| České Budějovice | 217 | x | 254 | 285 | 375 | 134 | 149 | 345 | 236 |
| Hradec Králové | 168 | 254 | x | 141 | 238 | 212 | 117 | 111 | 186 |
| Olomouc | 78 | 285 | 141 | x | 100 | 373 | 280 | 62 | 367 |
| Ostrava | 167 | 375 | 238 | 100 | X | 464 | 370 | 159 | 458 |
| Plzeň | 299 | 134 | 212 | 373 | 464 | x | 98 | 430 | 178 |
| Praha | 206 | 149 | 117 | 280 | 370 | 98 | x | 222 | 88 |
| Šumperk | 137 | 345 | 111 | 62 | 159 | 430 | 222 | x | 299 |
| Ústí nad Labem | 293 | 236 | 186 | 367 | 458 | 178 | 88 | 299 | x |

Table 5-27 Nearest neighbor method, Ústí nad Labem as the first city, result

Ústí nad Labem – Praha – Plzeň – České Budějovice – Brno – Olomouc – Šumperk – Hradec Králové – Ostrava – Ústí nad Labem

88+98+134+217+78+62+111+238+458 = 1484km

**The result:**

| First city | Circularize connected | Length |
|---|---|---|
| Brno | Brno – Olomouc – Šumperk – Hradec Králové – Praha – Ústí nad Labem – Plzeň – České Budějovice – Ostrava – Brno | 1310 |
| České Budějovice | České Budějovice – Plzeň – Praha – Ústí nad Labem – Hradec Králové – Šumperk – Olomouc – Brno – Ostrava – České Budějovice | 1299 |
| Hradec Králové | Hradec Králové – Šumperk – Olomouc – Brno – Ostrava – Praha – Ústí nad Labem – Plzeň – České Budějovice – Hradec Králové | 1442 |
| Olomouc | Olomouc – Šumperk – Hradec Králové – Praha – Ústí nad Labem – Plzeň – České Budějovice – Brno – Ostrava – Olomouc | 1174 |
| Ostrava | Ostrava – Olomouc – Šumperk – Hradec Králové – Praha – Ústí nad Labem – Plzeň – České Budějovice – Brno – Ostrava | 1174 |
| Plzeň | Plzeň – Praha – Ústí nad Labem – Hradec Králové – Šumperk - Olomouc – Brno – Ostrava – České Budějovice – Plzeň | 1299 |
| Praha | Praha – Ústí nad Labem – Plzeň – České Budějovice – Brno – Olomouc – Šumperk – Hradec Králové – Ostrava – Praha | 1468 |
| Šumperk | Šumperk – Olomouc – Brno – Ostrava – Hradec Králové – Praha – Ústí nad Labem – Plzeň – České Budějovice – Šumperk | 1407 |
| Ústí nad Labem | Ústí nad Labem – Praha – Plzeň – České Budějovice – Brno – Olomouc – Šumperk – Hradec Králové – Ostrava – Ústí nad Labem | 1484 |

Table 5-28 The result of nearest neighbor method

As we can see in the table we have 2 of the best results, now we will change the route to start in Ústí nad Labem:

1. Ústí nad Labem – Plzeň – České Budějovice – Brno – Ostrava – Olomouc - Šumperk – Hradec Králové – Praha – Ústí nad Labem
2. Ústí nad Labem – Plzeň – České Budějovice – Brno – Ostrava - Olomouc – Šumperk – Hradec Králové – Praha – Ústí nad Labem

As we can see, we have the same result.

### 5.2.2 Vogel approximation method

We use the same process like we did in chapter 5.1 for our first client; we will just show the differences and the result for this case.

This is the result from Vogel approximation Method:

| | Brno | ČB | HK | Olo. | Ost. | Plzeň | Praha | Šum. | ÚnL |
|---|---|---|---|---|---|---|---|---|---|
| Brno | x | 217 | 168 | 78 | 167 | 299 | 206 | 137 | 293 |
| ČB | 217 | x | 254 | 285 | 375 | 134 | 149 | 345 | 236 |
| HK | 168 | 254 | x | 141 | 238 | 212 | 117 | 111 | 186 |
| Olo. | 78 | 285 | 141 | x | 100 | 373 | 280 | 62 | 367 |
| Ost. | 167 | 375 | 238 | 100 | x | 464 | 370 | 159 | 458 |
| Plzeň | 299 | 134 | 212 | 373 | 464 | x | 98 | 430 | 178 |
| Praha | 206 | 149 | 117 | 280 | 370 | 98 | x | 222 | 88 |
| Šum. | 137 | 345 | 111 | 62 | 159 | 430 | 222 | X | 299 |
| ÚnL | 293 | 236 | 186 | 367 | 458 | 178 | 88 | 299 | x |

Table 5-29 Vogel approximation Method, final table

Ústí nad Labem – Praha – České Budějovice – Plzeň – Brno – Olomouc – Šumperk – Ostrava – Hradec Králové – Ústí nad Labem

88+149+134+299+78+62+159+238+186 = 1393km

### 5.2.3 Result

We used 2 different methods to optimize routes in the Czech Republic. The result from the nearest neighbor method is:

Ústí nad Labem – Plzeň – České Budějovice – Brno – Ostrava – Olomouc Šumperk – Hradec Králové – Praha – Ústí nad Labem = 1174 km

And the result from Vogel approximation method is:

Ústí nad Labem – Praha – České Budějovice – Plzeň – Brno – Olomouc – Šumperk – Ostrava – Hradec Králové – Ústí nad Labem = 1393 km

We got 2 different results and we chose the better result, which is the result from the nearest neighbor method:

Ústí nad Labem – Plzeň – České Budějovice – Brno – Ostrava – Olomouc Šumperk – Hradec Králové – Praha – Ústí nad Labem = 1174 km

### 5.2.4 Mayer method

The table shows the rates of multi-circuit task we sort points (rows and columns) by the distance from the central collection point, which itself can be omitted in the table, and add the column containing the requirements of individual sites. Denote the first column of this table (i.e., the first place to select the first orbital route) and the requirement in the first line, and striking out the first line. For each of the other places we compute its shipping requirement, and marked all the places where the sum is greater than the capacity of the vehicle, striking out in the first column cell in the row (usually, unless shipping requirements due to the disproportionately large capacity vehicles, such a case does not occur). From the not highlighted elements in the first column, we choose the minimum, if the choice is not clear; we choose the first such element in the sequence (uppermost). This indicates the location which we further assign to the currently designed circular route. We highlight the corresponding column and requirement in the corresponding row and strike out the line. We add up the marked requirements and for those places, where its requirement by adding to that total vehicle capacity is exceeded, again strike out in the labeled columns cells in the corresponding rows. From the not highlighted elements in the labeled columns we choose the minimum element, and thus the additional space orbital route, in the same way. We repeat the entire procedure until when comparing the capacities we strike out all the highlighted rates in the labeled columns. Thus, we have chosen the places for the first orbital route. We jot down them, highlight the respective columns and requirements and the rest of the table look the places for other routes in the same way (Šubrt a kolektiv, 2011, p 108).

The places in single routes are to be sorted. For this, we can use any of the methods for solving single-circuit problems (Šubrt a kolektiv, 2011, p 109).

### 5.2.4.1 Solution Mayer method

<u>Capacity of the truck:</u> 25 tons

<u>Central point:</u> Ústí nad Labem

We show two views on how to troubleshoot this method: the first will focus on the material (economic) interpretation of individual sub-steps algorithm then the second on the technical aspects (i.e. how it's all done in the table) (Šubrt a kolektiv, 2011, p 109).

Before we deal with the role, it is appropriate to estimate about how many vehicles will be needed for the entire distribution (i.e. how many cruise lines will have to be divided). The sum of the requirements is 46 tons, 25 tons capacity vehicles if the requirements lay out favorably, it could do two vehicles (Šubrt a kolektiv, 2011, p 109).

| | Brno | ČB | HK | Olomouc | Ostrava | Plzeň | Praha | Šumperk |
|---|---|---|---|---|---|---|---|---|
| Request [t] | 10 | 5 | 3 | 3 | 6 | 5 | 12 | 2 |

Table 5-30 Mayer Method, request by cities

In the first circuit will be included as the first city which is farthest from the central location (Ústí nad Labem), thus Ostrava.

| | Ostrava | Olomouc | Šumperk | Brno | ČB | HK | Plzeň | Praha | Request |
|---|---|---|---|---|---|---|---|---|---|
| Ostrava | x | 100 | 159 | 167 | 375 | 238 | 464 | 370 | 6 |
| Olomouc | 100 | x | 62 | 78 | 285 | 141 | 373 | 280 | 3 |
| Šumperk | 159 | 62 | x | 137 | 345 | 111 | 430 | 222 | 2 |
| Brno | 167 | 78 | 137 | x | 217 | 168 | 299 | 206 | 10 |
| České Budějovice | 375 | 285 | 345 | 217 | x | 254 | 134 | 149 | 5 |
| Hradec Králové | 238 | 141 | 111 | 168 | 254 | x | 212 | 117 | 3 |
| Plzeň | 464 | 373 | 430 | 299 | 134 | 212 | x | 98 | 5 |
| Praha | 370 | 280 | 222 | 206 | 149 | 117 | 98 | x | 12 |

Table 5-31 Mayer Method, the main table

We will highlight the route from Ostrava:

| | Ostrava | Olomouc | Šumperk | Brno | ČB | HK | Plzeň | Praha | Request |
|---|---|---|---|---|---|---|---|---|---|
| **Ostrava** | x | 100 | 159 | 167 | 375 | 238 | 464 | 370 | 6 |
| **Olomouc** | 100 | x | 62 | 78 | 285 | 141 | 373 | 280 | 3 |
| **Šumperk** | 159 | 62 | x | 137 | 345 | 111 | 430 | 222 | 2 |
| **Brno** | 167 | 78 | 137 | x | 217 | 168 | 299 | 206 | 10 |
| **České Budějovice** | 375 | 285 | 345 | 217 | x | 254 | 134 | 149 | 5 |
| **Hradec Králové** | 238 | 141 | 111 | 168 | 254 | x | 212 | 117 | 3 |
| **Plzeň** | 464 | 373 | 430 | 299 | 134 | 212 | x | 98 | 5 |
| **Praha** | 370 | 280 | 222 | 206 | 149 | 117 | 98 | x | 12 |

Table 5-32 Mayer Method, 1st step

Next step:

| | Ostrava | Olomouc | Šumperk | Brno | ČB | HK | Plzeň | Praha | Request |
|---|---|---|---|---|---|---|---|---|---|
| **Ostrava** | x | 100 | 159 | 167 | 375 | 238 | 464 | 370 | 6 |
| **Olomouc** | 100 | x | 62 | 78 | 285 | 141 | 373 | 280 | 3 |
| **Šumperk** | 159 | 62 | x | 137 | 345 | 111 | 430 | 222 | 2 |
| **Brno** | 167 | 78 | 137 | x | 217 | 168 | 299 | 206 | 10 |
| **České Budějovice** | 375 | 285 | 345 | 217 | x | 254 | 134 | 149 | 5 |
| **Hradec Králové** | 238 | 141 | 111 | 168 | 254 | x | 212 | 117 | 3 |
| **Plzeň** | 464 | 373 | 430 | 299 | 134 | 212 | x | 98 | 5 |
| **Praha** | 370 | 280 | 222 | 206 | 149 | 117 | 98 | x | 12 |

Table 5-33 Mayer Method, 2nd step

The next (closest from Ostrava) is Olomouc, for now the total capacity is 9 tones, so we can continue to another city.

| | Ostrava | Olomouc | Šumperk | Brno | ČB | HK | Plzeň | Praha | Request |
|---|---|---|---|---|---|---|---|---|---|
| Ostrava | x | 100 | 159 | 167 | 375 | 238 | 464 | 370 | 6 |
| Olomouc | 100 | x | 62 | 78 | 285 | 141 | 373 | 280 | 3 |
| Šumperk | 159 | 62 | x | 137 | 345 | 111 | 430 | 222 | 2 |
| Brno | 167 | 78 | 137 | x | 217 | 168 | 299 | 206 | 10 |
| České Budějovice | 375 | 285 | 345 | 217 | x | 254 | 134 | 149 | 5 |
| Hradec Králové | 238 | 141 | 111 | 168 | 254 | x | 212 | 117 | 3 |
| Plzeň | 464 | 373 | 430 | 299 | 134 | 212 | x | 98 | 5 |
| Praha | 370 | 280 | 222 | 206 | 149 | 117 | 98 | x | 12 |

Table 5-34 Mayer Method, 3rd step

The next (closest from Olomouc) is Šumperk, for now the total capacity is 11 tones, so we can continue to another city.

| | Ostrava | Olomouc | Šumperk | Brno | ČB | HK | Plzeň | Praha | Request |
|---|---|---|---|---|---|---|---|---|---|
| Ostrava | x | 100 | 159 | 167 | 375 | 238 | 464 | 370 | 6 |
| Olomouc | 100 | x | 62 | 78 | 285 | 141 | 373 | 280 | 3 |
| Šumperk | 159 | 62 | x | 137 | 345 | 111 | 430 | 222 | 2 |
| Brno | 167 | 78 | 137 | x | 217 | 168 | 299 | 206 | 10 |
| České Budějovice | 375 | 285 | 345 | 217 | x | 254 | 134 | 149 | 5 |
| Hradec Králové | 238 | 141 | 111 | 168 | 254 | x | 212 | 117 | 3 |
| Plzeň | 464 | 373 | 430 | 299 | 134 | 212 | x | 98 | 5 |
| Praha | 370 | 280 | 222 | 206 | 149 | 117 | 98 | x | 12 |

Table 5-35 Mayer Method, 4th step

The next (closest from Šumperk) is Brno, for now the total capacity is 21 tones, so we can continue to another city.

| | Ostrava | Olomouc | Šumperk | Brno | ČB | HK | Plzeň | Praha | Request |
|---|---|---|---|---|---|---|---|---|---|
| Ostrava | x | 100 | 159 | 167 | 375 | 238 | 464 | 370 | 6 |
| Olomouc | 100 | x | 62 | 78 | 285 | 141 | 373 | 280 | 3 |
| Šumperk | 159 | 62 | x | 137 | 345 | 111 | 430 | 222 | 2 |
| Brno | 167 | 78 | 137 | x | 217 | 168 | 299 | 206 | 10 |
| České Budějovice | 375 | 285 | 345 | 217 | x | 254 | 134 | 149 | 5 |
| Hradec Králové | 238 | 141 | 111 | 168 | 254 | x | 212 | 117 | 3 |
| Plzeň | 464 | 373 | 430 | 299 | 134 | 212 | x | 98 | 5 |
| Praha | 370 | 280 | 222 | 206 | 149 | 117 | 98 | x | 12 |

Table 5-36 Mayer Method, 5th step

The next (closest from Brno) is Hradec Králové, for now the total capacity is 24 tones, so we can continue to another city.

| | Ostrava | Olomouc | Šumperk | Brno | ČB | HK | Plzeň | Praha | Request |
|---|---|---|---|---|---|---|---|---|---|
| Ostrava | x | 100 | 159 | 167 | 375 | 238 | 464 | 370 | 6 |
| Olomouc | 100 | x | 62 | 78 | 285 | 141 | 373 | 280 | 3 |
| Šumperk | 159 | 62 | x | 137 | 345 | 111 | 430 | 222 | 2 |
| Brno | 167 | 78 | 137 | x | 217 | 168 | 299 | 206 | 10 |
| České Budějovice | 375 | 285 | 345 | 217 | x | 254 | 134 | 149 | 5 |
| Hradec Králové | 238 | 141 | 111 | 168 | 254 | x | 212 | 117 | 3 |
| Plzeň | 464 | 373 | 430 | 299 | 134 | 212 | x | 98 | 5 |
| Praha | 370 | 280 | 222 | 206 | 149 | 117 | 98 | x | 12 |

Table 5-37 Mayer Method, 6th step

The next (closest from Hradec Králové) is Praha, but as we can see, the total capacity would be 36 tones, but the maximum capacity for one car is 25 tones. So now we have to start second route from Ústí nad Labem.

In the second circuit will be included as the first city which is farthest from the central location (Ústí nad Labem), thus České Budějovice.

| | Ostrava | Olomouc | Šumperk | Brno | ČB | HK | Plzeň | Praha | Request |
|---|---|---|---|---|---|---|---|---|---|
| **Ostrava** | x | 100 | 159 | 167 | 375 | 238 | 464 | 370 | 6 |
| **Olomouc** | 100 | x | 62 | 78 | 285 | 141 | 373 | 280 | 3 |
| **Šumperk** | 159 | 62 | x | 137 | 345 | 111 | 430 | 222 | 2 |
| **Brno** | 167 | 78 | 137 | x | 217 | 168 | 299 | 206 | 10 |
| **České Budějovice** | 375 | 285 | 345 | 217 | x | 254 | 134 | 149 | 5 |
| **Hradec Králové** | 238 | 141 | 111 | 168 | 254 | x | 212 | 117 | 3 |
| **Plzeň** | 464 | 373 | 430 | 299 | 134 | 212 | x | 98 | 5 |
| **Praha** | 370 | 280 | 222 | 206 | 149 | 117 | 98 | x | 12 |

Table 5-38 Mayer Method, second route, 1st step

The next step:

| | Ostrava | Olomouc | Šumperk | Brno | ČB | HK | Plzeň | Praha | Request |
|---|---|---|---|---|---|---|---|---|---|
| **Ostrava** | x | 100 | 159 | 167 | 375 | 238 | 464 | 370 | 6 |
| **Olomouc** | 100 | x | 62 | 78 | 285 | 141 | 373 | 280 | 3 |
| **Šumperk** | 159 | 62 | x | 137 | 345 | 111 | 430 | 222 | 2 |
| **Brno** | 167 | 78 | 137 | x | 217 | 168 | 299 | 206 | 10 |
| **České Budějovice** | 375 | 285 | 345 | 217 | x | 254 | 134 | 149 | 5 |
| **Hradec Králové** | 238 | 141 | 111 | 168 | 254 | x | 212 | 117 | 3 |
| **Plzeň** | 464 | 373 | 430 | 299 | 134 | 212 | x | 98 | 5 |
| **Praha** | 370 | 280 | 222 | 206 | 149 | 117 | 98 | x | 12 |

Table 5-39 Mayer Method, second route, 2nd step

The next (closest from České Budějovice) is Plzeň, for now the total capacity is 10 tones, so we can continue to another city. The last city is Prague and the total request is 22 tones.

<u>The first route is:</u>

Ústí nad Labem – Ostrava – Olomouc – Šumperk – Brno – Hradec Králové - Ústí nad Labem = 24 tones

It’s still sort of being in the different orbital paths. The first group includes, in addition Ústí nad Labem and 5 other cities. Now, using the nearest neighbor method will solve what order will be optimal. We show only the final table, the remaining tables are in chapter 8 as a supplement.

| | Ostrava | Olomouc | Šumperk | Brno | HK | ÚnL |
|---|---|---|---|---|---|---|
| Ostrava | x | 100 | 159 | 167 | 238 | 458 |
| Olomouc | 100 | x | 62 | 78 | 141 | 367 |
| Šumperk | 159 | 62 | x | 137 | 111 | 299 |
| Brno | 167 | 78 | 137 | X | 168 | 293 |
| Hradec Králové | 238 | 141 | 111 | 168 | x | 186 |
| Ústí nad Labem | 458 | 367 | 299 | 293 | 186 | x |

Table 5-40 Mayer Method, final table of first route

Ústí nad Labem – Šumperk – Olomouc – Brno – Ostrava – Hradec Králové – Ústí nad Labem

299+62+78+167+238+186 = 1030km

<u>The second route is:</u>

Ústí nad Labem – České Budějovice – Plzeň – Praha – Ústí nad Labem = 22 t

To optimize the route we will use the nearest neighbor method. We show only the final table, the remaining tables are in chapter 8 as a supplement.

| | ČB | Plzeň | Praha | ÚnL |
|---|---|---|---|---|
| České Budějovice | x | 134 | 149 | 236 |
| Plzeň | 134 | x | 98 | 178 |
| Praha | 149 | 98 | x | 88 |
| Ústí nad Labem | 236 | 178 | 88 | X |

Table 5-41 Mayer Method, final table of second route

Ústí nad Labem – Plzeň – České Budějovice – Praha – Ústí nad Labem

178+134+149+88 = 549km

**The result:**

The Client will provide 2 different routes:

Ústí nad Labem – Šumperk – Olomouc – Brno – Ostrava – Hradec Králové – Ústí nad Labem = 24 tones

299+62+78+167+238+186 = 1030km

Ústí nad Labem – Plzeň – České Budějovice – Praha – Ústí nad Labem = 22 tones

178+134+149+88 = 549km

# 6 Conclusion

This diploma thesis ,,Optimization of Transportation Routes between Customers and its Suppliers”, was dedicated to the optimization of transportation routes for a Taiwanese company called Polet Wunik, which mediates suppliers and consumers for its clients. This thesis dealt with specific real cases where the Taiwanese company cooperates with Czech companies. The first part of this thesis was devoted to the literature review, which describes the optimization methods that can be used to calculate the optimization of possible routes. The second part describes the three companies that need to optimize its transportation routes, where routes are a big part of its cooperation.

The main issue was to explain and subsequently apply traveling salesman problem on the client’s cases where approximation methods were used. Its applications, achieving the optimal solution, provide an advantage in terms of saving costs (e.g. fuel, time, depreciation of a car…).

The goal of this diploma thesis was to suggest and optimize the transportation routes from the supplier to the customer. We had two different cases:

Client BUSHMANN – the client would like to enter the Taiwanese market and the PWISS Company will provide customers who would be interested in buying its goods. The contract is going to be about transportation from Czech Republic to 9 cities in Taiwan, where BUSHMANN is going to sell its products. This diploma thesis optimized the transportation routes in Taiwan. For optimizing the routes, there were used 2 methods, the nearest neighbor method and Vogel Approximate method.

We got 2 best results, both with the same amount of kilometers. There was a difference in the directions. The directions were opposite, so we actually got the same result from both methods. It depends on the company which direction the company prefers. We will introduce to the clients both options and the company will choose which route the company prefers. It should be the direction Taoyuan – Taipei – Keelung – Hualien – Kaohsiung – Tainan – Chiayi – Taichung – Hsinchu – Taoyuan = 978 km because the length of the part of the route, which the track goes fully loaded, is shorter so it means more cost effective and it will optimize workload capacity of the truck.

Client Šumavský pramen – the client would like to find a cheaper supplier of aqua mats from Asians market. In this diploma thesis there was a focus on logistics from Taiwan to Šumavský pramen's clients in the Czech Republic. In the beginning, the contract consisted of just small amount of containers, because the client of Šumavský pramen wants to first try the service and see if the business with PWISS is good and later on the client is planning to have higher amount of containers which means more difficult logistic system. In this case there were 2 solutions, first for smaller amounts of containers and second for higher amounts of containers. In the first solution there were used 2 methods, the nearest neighbor method and Vogel Approximate method. In the second solution only Mayer Method was used.

For the first solution we got 2 different results and we chose the better one, which means the result from nearest neighbor method: Ústí nad Labem – Plzeň – České Budějovice – Brno – Ostrava – Olomouc Šumperk – Hradec Králové – Praha – Ústí nad Labem = 1174 km.

For the second solution client will provide 2 different routes: Ústí nad Labem – Šumperk – Olomouc – Brno – Ostrava – Hradec Králové – Ústí nad Labem = 24 tones = 1030km and Ústí nad Labem – Plzeň – České Budějovice – Praha – Ústí nad Labem = 22 tones = 549km.

In this thesis it was demonstrated that using an optimization methods we can reduce logistics costs, time and also satisfy clients' requirements.

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https://maps.google.com/ - to find distance between cities

# 8 Supplements

Figure 1 - Logo of client 1

Figure 2 - Products of BUSHMANN client

(http://www.bushmanwear.eu/).

ŠUMAVSKÝ PRAMEN

BALENÁ PRAMENITÁ VODA

**Figure 3 - Logo of client 2**

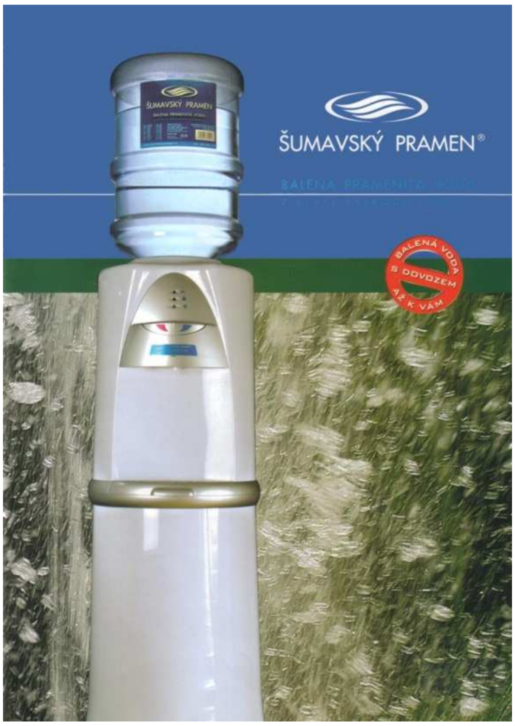


**Figure 4 - Aqua mats from Šumavský pramen client**

(http://www.sumavskypramen.cz/)

| | Chiayi | Hsinchu | Hualien | Kaohsiung | Keelung | Taichung | Tainan | Taipei | Taoyuan | Dif | Dif | Dif | Dif | Dif | Dif | Dif |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Chiayi** | x | 178 | 251 | 140 | 270 | 144 | 53 | 256 | 225 | 87 | | | | | | |
| **Hsinchu** | 178 | x | 254 | 316 | 100 | 116 | 218 | 85 | 56 | 29 | 29 | 29 | | | | |
| **Hualien** | 251 | **254** | x | 261 | 177 | 353 | 292 | 176 | 208 | 1 | 1 | 1 | 1 | 1 | 1 | 31 |
| **Kaohsiung** | **140** | **316** | 261 | x | 407 | 282 | 110 | 394 | 362 | 30 | 121 | 21 | 55 | 101 | | |
| **Keelung** | 270 | 100 | 177 | 407 | x | 205 | 311 | 21 | 55 | 34 | 34 | 34 | 34 | 34 | 34 | |
| **Taichung** | 144 | **116** | 353 | 282 | 205 | x | 185 | 189 | 159 | 28 | 28 | 28 | 15 | | | |
| **Tainan** | **53** | 218 | 292 | 110 | 311 | 185 | x | 296 | 265 | 57 | 75 | | | | | |
| **Taipei** | 256 | 85 | 176 | 394 | 21 | 189 | 296 | x | 40 | 19 | 19 | 19 | 19 | 19 | 19 | 45 |
| **Taoyuan** | 225 | 56 | 208 | 362 | **55** | 159 | 265 | 40 | X | 15 | 15 | 15 | 15 | 15 | 15 | 1 |
| **Difference** | 87 | 29 | 1 | 30 | 34 | 28 | 57 | 19 | 15 | | | | | | | |
| **Difference** | 4 | 29 | 1 | 151 | 34 | 43 | | 19 | 15 | | | | | | | |
| **Difference** | 34 | 29 | 1 | | 34 | 43 | | 19 | 15 | | | | | | | |
| **Difference** | 81 | 29 | 1 | | 34 | | | 19 | 15 | | | | | | | |
| **Difference** | | 29 | | | 34 | | | 19 | 15 | | | | | | | |
| **Difference** | | 29 | | | 34 | | | 19 | 15 | | | | | | | |
| **Difference** | | 29 | | | 122 | | | | 168 | | | | | | | |

**Table 8-1 Final Vogel approximation method, client 1**

| | Brno | ČB | HK | Olo. | Ost. | Plzeň | Praha | Šum. | ÚnL | Dif | Dif | Dif | Dif | Dif | Dif | Dif |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Brno** | x | 217 | 168 | 78 | 167 | 299 | 206 | 137 | 293 | 59 | 59 | 59 | 59 | 59 | 89 | |
| **ČB** | 217 | x | 254 | 285 | 375 | 134 | 149 | 345 | 236 | 15 | 83 | | | | | |
| **HK** | 168 | 254 | x | 141 | 238 | 212 | 117 | 111 | 186 | 6 | 30 | 30 | 30 | | | |
| **Olo.** | 78 | 285 | 141 | x | 100 | 373 | 280 | 62 | 367 | 16 | 16 | 16 | 16 | 16 | | |
| **Ost.** | 167 | 375 | 238 | 100 | x | 464 | 370 | 159 | 458 | 59 | 59 | 59 | 59 | 59 | 67 | 71 |
| **Plzeň** | 299 | 134 | 212 | 373 | 464 | x | 98 | 430 | 178 | 36 | 44 | 34 | 87 | 74 | 74 | 165 |
| **Praha** | 206 | 149 | 117 | 280 | 370 | 98 | x | 222 | 88 | 10 | 19 | 32 | | | | |
| **Šum.** | 137 | 345 | 111 | 62 | 159 | 430 | 222 | x | 299 | 49 | 49 | 49 | 49 | 49 | 26 | 48 |
| **ÚnL** | 293 | 236 | 186 | 367 | 458 | 178 | 88 | 299 | x | 90 | | | | | | |
| **Dif** | 59 | 15 | 6 | 16 | 59 | 36 | 10 | 49 | 90 | | | | | | | |
| **Dif** | 59 | 15 | 6 | 16 | 59 | 36 | | 49 | 8 | | | | | | | |
| **Dif** | 59 | 68 | 6 | 16 | 59 | | | 49 | 8 | | | | | | | |
| **Dif** | 59 | | 30 | 16 | 59 | | | 49 | 107 | | | | | | | |
| **Dif** | 59 | | 30 | 16 | 59 | | | 75 | | | | | | | | |
| **Dif** | 30 | | 57 | 22 | 8 | | | | | | | | | | | |
| **Dif** | 132 | | 127 | | 305 | | | | | | | | | | | |

**Table 8-2 Final table Vogel approximation method, client 2**

| | Ostrava | Olomouc | Šumperk | Brno | HK | ÚnL |
|---|---|---|---|---|---|---|
| Ostrava | x | 100 | 159 | 167 | 238 | 458 |
| Olomouc | 100 | x | 62 | 78 | 141 | 367 |
| Šumperk | 159 | 62 | x | 137 | 111 | 299 |
| Brno | 167 | 78 | 137 | X | 168 | 293 |
| Hradec Králové | 238 | 141 | 111 | 168 | x | 186 |
| Ústí nad Labem | 458 | 367 | 299 | 293 | 186 | x |

Table 8-3 Mayer Method, first route, Ostrava as a first city, result

Total: 1192km

| | Ostrava | Olomouc | Šumperk | Brno | HK | ÚnL |
|---|---|---|---|---|---|---|
| Ostrava | x | 100 | 159 | 167 | 238 | 458 |
| Olomouc | 100 | x | 62 | 78 | 141 | 367 |
| Šumperk | 159 | 62 | x | 137 | 111 | 299 |
| Brno | 167 | 78 | 137 | X | 168 | 293 |
| Hradec Králové | 238 | 141 | 111 | 168 | x | 186 |
| Ústí nad Labem | 458 | 367 | 299 | 293 | 186 | x |

Table 8-4 Mayer Method, first route, Olomouc as a first city, result

Total: 1333km

| | Ostrava | Olomouc | Šumperk | Brno | HK | ÚnL |
|---|---|---|---|---|---|---|
| Ostrava | x | 100 | 159 | 167 | 238 | 458 |
| Olomouc | 100 | x | 62 | 78 | 141 | 367 |
| Šumperk | 159 | 62 | x | 137 | 111 | 299 |
| Brno | 167 | 78 | 137 | x | 168 | 293 |
| Hradec Králové | 238 | 141 | 111 | 168 | x | 186 |
| Ústí nad Labem | 458 | 367 | 299 | 293 | 186 | x |

Table 8-5 Mayer Method, first route, Šumperk as a first city, result

Total: 1030km

| | Ostrava | Olomouc | Šumperk | Brno | HK | ÚnL |
|---|---|---|---|---|---|---|
| Ostrava | x | 100 | 159 | 167 | 238 | 458 |
| Olomouc | 100 | x | 62 | 78 | 141 | 367 |
| Šumperk | 159 | 62 | x | 137 | 111 | 299 |
| Brno | 167 | 78 | 137 | x | 168 | 293 |
| Hradec Králové | 238 | 141 | 111 | 168 | x | 186 |
| Ústí nad Labem | 458 | 367 | 299 | 293 | 186 | x |

Table 8-6 Mayer Method, first route, Brno as a first city, result

Total: 1062km

| | Ostrava | Olomouc | Šumperk | Brno | HK | ÚnL |
|---|---|---|---|---|---|---|
| Ostrava | x | 100 | 159 | 167 | 238 | 458 |
| Olomouc | 100 | x | 62 | 78 | 141 | 367 |
| Šumperk | 159 | 62 | x | 137 | 111 | 299 |
| Brno | 167 | 78 | 137 | x | 168 | 293 |
| Hradec Králové | 238 | 141 | 111 | 168 | x | 186 |
| Ústí nad Labem | 458 | 367 | 299 | 293 | 186 | x |

Table 8-7 Mayer Method, first route, Hradec Králové as a first city, result

Total: 1062km

| | Ostrava | Olomouc | Šumperk | Brno | HK | ÚnL |
|---|---|---|---|---|---|---|
| Ostrava | x | 100 | 159 | 167 | 238 | 458 |
| Olomouc | 100 | x | 62 | 78 | 141 | 367 |
| Šumperk | 159 | 62 | x | 137 | 111 | 299 |
| Brno | 167 | 78 | 137 | x | 168 | 293 |
| Hradec Králové | 238 | 141 | 111 | 168 | x | 186 |
| Ústí nad Labem | 458 | 367 | 299 | 293 | 186 | x |

Table 8-8 Table 48 Mayer Method, first route, Ústí nad Labem as a first city, result

Total: 1062km

| | ČB | Plzeň | Praha | ÚnL |
|---|---|---|---|---|
| České Budějovice | x | 134 | 149 | 236 |
| Plzeň | 134 | x | 98 | 178 |
| Praha | 149 | 98 | x | 88 |
| Ústí nad Labem | 236 | 178 | 88 | x |

**Table 8-9 Mayer Method, second route, České Budějovice as a first city, result**

Total: 556 km

| | ČB | Plzeň | Praha | ÚnL |
|---|---|---|---|---|
| České Budějovice | x | 134 | 149 | 236 |
| Plzeň | 134 | x | 98 | 178 |
| Praha | 149 | 98 | x | 88 |
| Ústí nad Labem | 236 | 178 | 88 | x |

**Table 8-10 Mayer Method, second route, Plzeň as a first city, result**

Total: 556km

| | ČB | Plzeň | Praha | ÚnL |
|---|---|---|---|---|
| České Budějovice | x | 134 | 149 | 236 |
| Plzeň | 134 | x | 98 | 178 |
| Praha | 149 | 98 | x | 88 |
| Ústí nad Labem | 236 | 178 | 88 | x |

**Table 8-11 Mayer Method, second route, Praha as a first city, result**

Total: 549km

| | ČB | Plzeň | Praha | ÚnL |
|---|---|---|---|---|
| České Budějovice | x | 134 | 149 | 236 |
| Plzeň | 134 | x | 98 | 178 |
| Praha | 149 | 98 | x | 88 |
| Ústí nad Labem | 236 | 178 | 88 | x |

**Table 8-12 Mayer Method, second route, Ústí nad Labem as a first city, result**

Total: 556km