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Improving the performance of Service Network through Location-based Optimization and Analysis of - a case study on postal service in a city in Northern Norway

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Abstract (max 150 words): For improving the service facility's availability, efficiency and accessibility, an experimentation is carried out in this paper. Mathematical modelling based on three classic facility location models. The purpose of this paper is to try to find an optimal solution for balance all three features of service facility buildings, thereby service network performance improves.	

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SHUO YANG

Abstract

Everyone needs to be served, and a service network provides a set of services and/or help to please the people involved. No matter who is the service provider, government or retailer, there always been a clash between them and customers. Service providers are trying their best to serve customers as many as possible with a limitation of cost, while the satisfaction of customer might be neglected at the same time. In order to find a balance between objectives of both customers and service providers. Three concepts: Availability, Efficiency and Accessibility are proposed in this paper corresponding to three classic facility location mathematical models: set covering location model, maximal covering location and p-median models. In addition, a real-world case study of postal service network in a city in Northern Norway is included under the purpose of improving the service performance based on the three concepts mention above. Excel Solver is applied for simulating all three covering mathematical models

1. Introduction

1.1 Research background and significance

A service network refers to a series of activities that coordinate the flow of goods, information, financial resources and services among a network of business partners to create value for their customers [1]. In supply chain management research, the main goal of the service network is to minimize costs while maximizing value creation and efficiency [1]. Although there are several ways to improve the performance of service network, an analysis based on service facility location is studied in this paper.

As the name implies, service facilities are facilities that can provide services to the public. It may include education, health care, culture, sports, transportation, social welfare and security, after-sale maintenance, commercial financial service, postal, telecommunications and so on. Service facilities provide resources and services for the public's survival and development, therefore the rationality of service facilities layout affects directly the fairness and service utilization of service resources.

The study of facility location has always been a subject throughout the human history. In the ancient time, decisions of site selection were usually based on experience, sensible intuition or even superstition, which were excessive subjectivity and lack of scientific foundation. The modern site selection problem was first proposed by Alfred Weber in 1909 [2]. In his research, Weber was trying to locate a warehouse with the aim of minimizing the carriage distances between warehouse and customers. The success of this paper's publication indicated that human started to solve facility location problem based on science, and it would definitely bring positive influence on both human's subsistence and social development.

No matter under what kind of social environment and historical conditions, human society is inseparable from the facility location problem. Facility location is a long-term, strategic decision which has great impacts on both social organizations and human production activities. The quality of facility location decision influences service methods, service quality, service efficiency and the cost of service. Correct facility location decision will bring convenience to people's life, reduce costs, expand profits or market share, improve service efficiency and competitiveness. While incorrect decision always leads to inconvenience, loss and even disaster. Nowadays, the problem of facility location is related to many aspects, such as economic, political, cultural, social and ecological. It has already become to a comprehensive systematic engineering, and the study of facility location has undoubtedly great realistic significance for both public service facilities and commercial facilities.

Location of service facilities is a central issue of urban planning and development. The harmony between human demand and service supply is directly affected by rationality of service facility distribution and the fairness of resource allocation in urban construction and development. In this paper, a location-based study of postal service is performed as an example. Its purpose is to achieve a reasonable allocation of social service resources through the discussion on location of service facilities, so that the public could benefit the results of urban construction and development, thereby improving their life qualities.

1.2 Problem and purpose statement

Since the 1960s, the problem of service facility location has been researched widely by scholars in various fields all over the world. In general, the study on the location of service facilities at present has following characteristics:

1) The location of service facility is normally designed from the perspective of service provider while analysis based on customer demand is imperfect;
2) Most of the location of service facilities is focus on complete coverage, and the description of demand coverage is not in line with the actual situation;
3) The uncertainty of service network performance caused by service facilities is rarely involved in previous researches.

Because of the difficulty in balancing responsiveness, efficiency and availability, the location problem of service facility has always been a thorny problem for both academics and practitioners [3]. Facilities are important in the service network in terms of responsiveness and efficiency [4]. Response time is the amount of time it takes for a customer to receive an order, and the availability is the probability of providing a product and/or service at service facility when customer order or the customer himself/herself arrives [4].

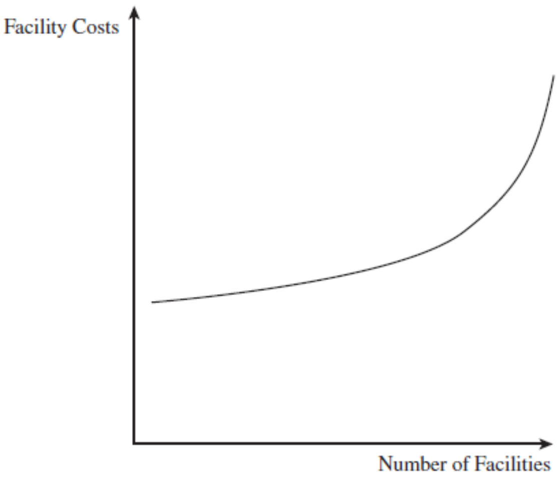


Figure 1 Relationship Between Number of Facilities and Facility Costs [4]

Figure 1 shows the relationship between facility cost and number of facilities. In this figure, facility cost is getting high along with the number of facilities increases. For controlling investment and/or pursue the maximization of the interests, service providers are obviously willing to deliver services and/or products to the maximum number of customers rely on facilities as few as possible. This centralization of facilities increases a company's efficiency. Whereas, as many of the company's customers are most likely located far away from company's facilities [4].

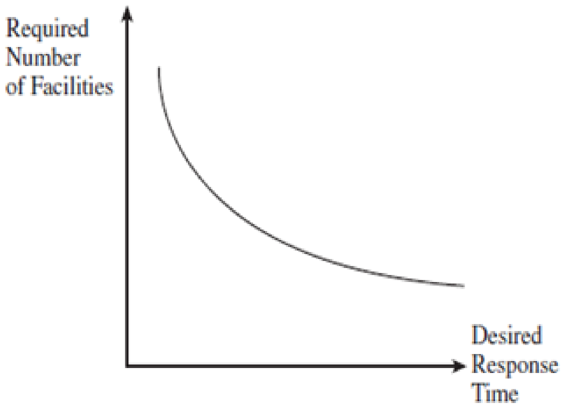


Figure 2 Relationship between required number of facilities and desired response time [4]

The relationship between the number of facilities and desired response time is shown in figure 2 above, and the desired response time is increasing along with the number of facilities decreases. Most of the customers today do not have that much time and/or patience to travel a long distance or wait in line because they prefer to be served immediately and appropriately [3]. Due to the pursuits of objective are different, a clash between service providers and customers arises. On the one hand, the service network of a company contains as many of facilities close to their customer improves both availability, responsiveness and accessibility in terms of customer demands, but on the other hand investment and operating cost also increase. In contrast, a limited number of facilities in a company's service network will decrease the cost under the premise of sacrificing response time and the customer satisfaction but increasing the efficiency of service network.

Hence, the core point is to determine a proper quantity and locations of service facilities, so that the existing performance of service network could be improved. Furthermore, finding a desired balance between corporate profit and customer satisfaction.

1.3 General idea and main innovations

Based on relative research literatures and theories, the article first puts forward a discussion on the performance of postal service network based on location in a city in northern Norway. Paper introduces "accessibility", "efficiency" and "availability" three concepts and then analyse existing locations of postal service facilities in the city under the help of three different mathematical models respectively. Finally, the paper brings forward some reasonable suggestions after comparing the results with the actual situation for improving the performance of existing postal service network.

Comparing with the current research achievements, main innovations of this article reflect in three aspects.

1.3.1 Location analysis of Service facility based on accessibility

Due to accessibility is a key concept of evaluating the layout of service facilities, many companies regard it as an important principle of service facilities' layout. Accessibility is affected by many factors, and the spatial accessibility emphasizes the spatial property of accessibility.

There are many explanations of accessibility. It can be considered as the effort required to arrive the finish line, such as distance costs, travel time or economic expenses [5]. The essence of accessibility refers to "the easiness by which people can reach the desired activity sites" [6]. Thus, the accessibility of the service facilities is the spatial relationship between the location of service facilities and the customers. Accessibility is a fundamental determinant of the utilization of service facilities. The basic principle of human activities is gaining resources and services as many as possibility through necessary effort, and accessibility is the important concept of characterizing this law [7].

The concept of "Accessibility" is introduced into this paper due to its feature mentioned above, and this method aims to minimize the total/average travel distance between customer and service facility in service network. Under the help of mathematical model, the accessibility of postal service facilities in a city in northern Norway is researched.

1.3.2 Location analysis of Service facility based on efficiency

"Efficient frontier" perhaps is the most important concept if a company is planning to locate a service facility [8]. It refers to a portfolio which provides the highest return rate under the condition of specified variables. In general, having more service facilities will reduce the service response time, however, the cost increases. The relationship between cost and service level is showed below in figure 3:

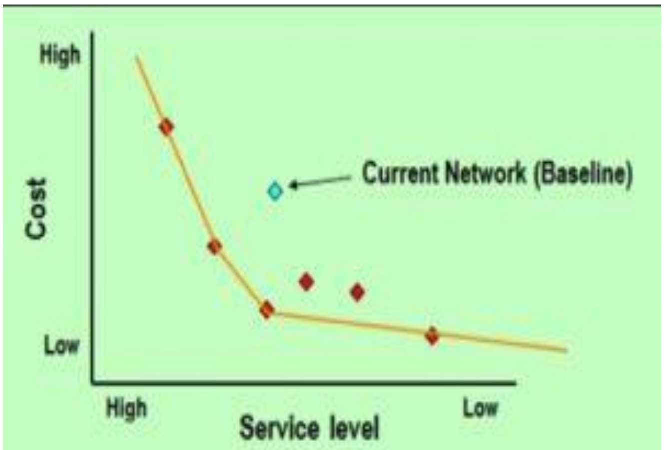


Figure3 Relationship Between Cost and Service level [8]

This methodology aims to maximize the satisfaction of customer demands with limited number of service facilities. With applying a mathematical model, the efficiency of postal service facilities in a city in northern Norway is researched.

1.3.3 Location analysis of Service facility based on availability

As mentioned before, service availability is the probability of accepting service from service provider when a customer arrives at a service facility [4]. It implies whenever and wherever a service is needed by a customer, the service ability is accessible.

Availability of the service facility location explores whether the location of service facility is match for demand of target groups from the perspective of space. And the opportunity for each resident to obtain service should be equal. However, the service supply has a certain service radius. The intensity of service center is becoming weak along with the distance from the center expands. It is notable that the mathematical model applied in this part specifies the maximum radius and ensures that each demand point is serviced by at least one facility.

1.4 Organization of this article

1.4.1 Report outline

This part provides a short synopsis for each chapter in order to manifest the outline of the report.

Chapter 1 aims at the site selection problem, raises a question about service performance of postal network in a city in northern Norway. The general idea and main innovations of this paper are provided subsequently in this chapter.

Chapter 2 reviews the previous literatures with respect to facility location problem, and provides inspiration for follow-up research.

Three mathematical models are introduced into chapter 3 with respect to paper's three innovations: "accessibility", "efficiency" and "availability" separately.

Based on the different mathematical models, three different experiments are studied respectively in chapter 4.

Inheriting and combining earlier work with real conditions, chapter 5 analyses the facilities distribution situation of an existing postal service network in a city in northern Norway.

Chapter 6 is result analysis and conclusion

Chapter 7 lists all references.

1.4.2 Structure diagram

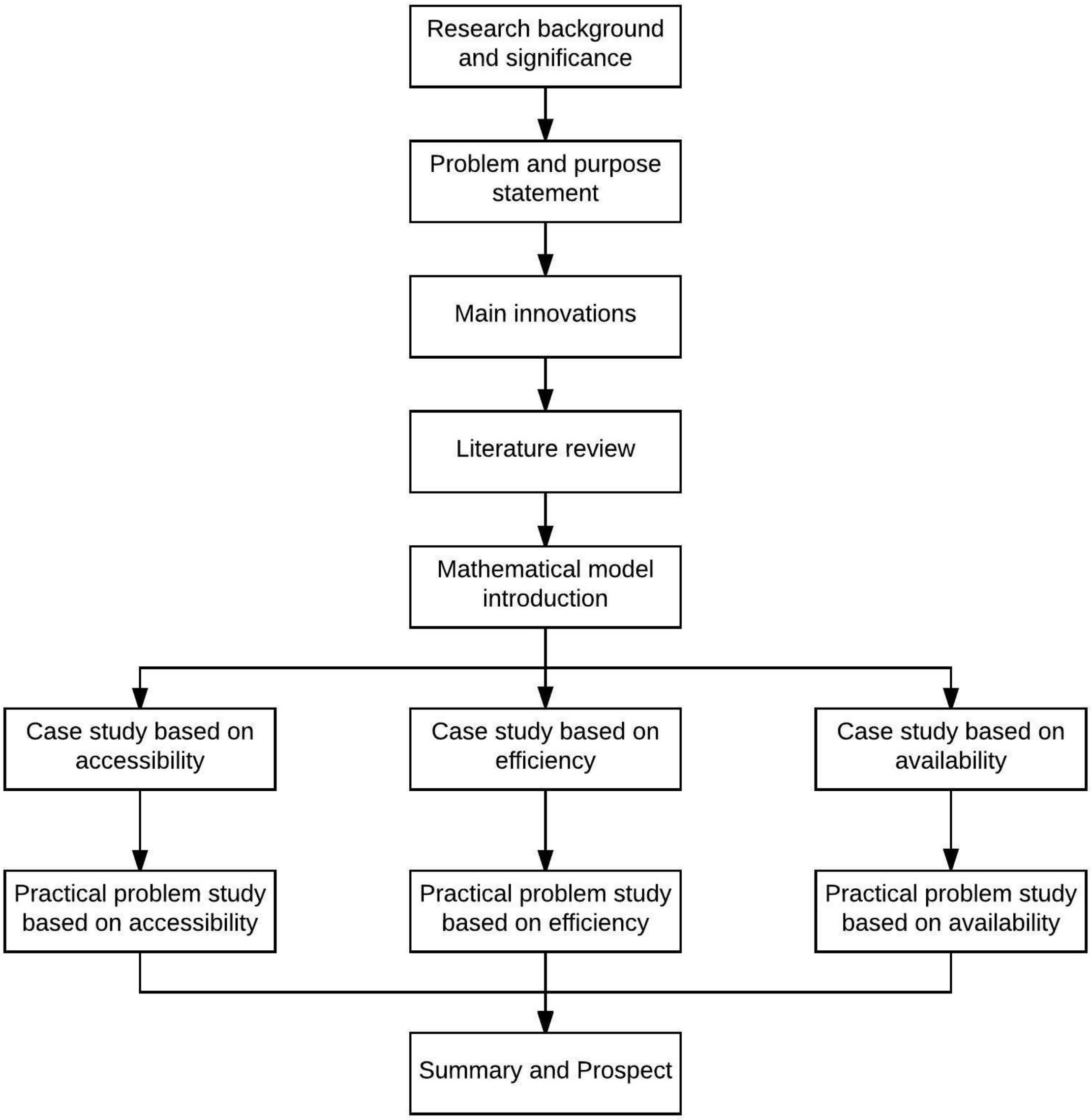


Figure 4 Paper structure diagram

2. Previous research on facility location problem

As mentioned in chapter 1, modern facility location problem originated in 1909. In order to obtain the minimum total travel distance between a warehouse and several customers, Alfred Weber established a median problem mathematical model in “Euclidean space” [2]. This is the famous Weber problem. Since then, problem of facility location attracts many scholars from different disciplines and fields, and study of this problem becomes also diversified.

2.1 Classification of facility location problem

The optimal location problem refers to build one or several optimal facilities to provide best service for existing facilities. A set of facilities here are generalized: it can be facilities that provide services or facilities need to be served.

Facility location problem can be divided into two aspects in terms of network location: continuous location problem and discrete location problem [9]. Discrete location problem is also known as the vertex location problem where facility candidate points are identified beforehand as nodes on a graph [10]. Demands arise on the nodes generally and the quantity of candidate locations has a limitation in discrete location problem [11]. However, the objective of continuous location problem is to “generate” nodes for locating new facilities relative to a set of existing facilities situated at given points in the space [10]. Continuous location problem is called also absolute location problem. Based on the above explanation of two different types of facility location problems, this paper will focus on discrete location problem.

2.2 Classic theoretical basis of discrete facility location

As shown in figure 5 below, Mark S. DASKIN classified discrete location models by subdividing the class into three broad aspects in his research in 2008 [11].

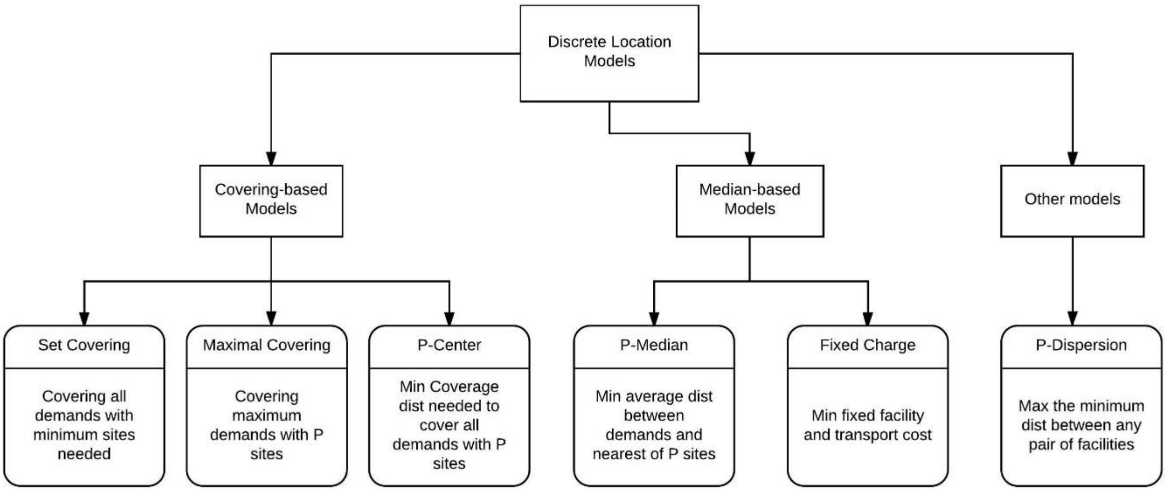


Figure 5 Three broad aspects of discrete location models [11]

Distance or some measures more or less functionally related to distance (e.g., travel time or cost, demand satisfaction) is fundamental to discrete location problem [12]. According to DASKIN's research, demand node is considered to be served if and only if the supposed critical coverage distance or time are "covered" or "served adequately" in covering-based models [11]. In median-based models, the weighted demand average distance between a demand site and facility is minimized [11]. Models satisfy neither of two previous models belong to the category of other models. For instance, p-dispersion model which maximizes the minimum distance between any two of facilities.

Because of their respective features and restrictions, different category of discrete location model is applied to different kinds of facility locations. Table 1 classifies different facility types with respect to different discrete location models.

Table 1 – Facility categories based on different discrete location models.

Location model Types	Key Features	Domain area	Instances
Covering-based Models	Meeting critical coverage distance	Emergency services Designing	Fire station; Healthcare emergency, etc.
Median-based Models	Average/ total distance Minimization	Distribution planning Contexts	Schools; Police patrol area, etc.
Other Models (p-dispersion)	Maximizing minimum distance between any pair of facilities	Catering industry Locating	Franchise outlets; KFC; Weapon supplies, etc.

After having been inspired by DASKIN's theory, a large amount of literature review carried out next on the basis of three categories of discrete location models. In addition, some literatures may not precisely be divided into the following three categories because facility location models applied by author in an article can be various.

2.2.1 Literature review based on covering-based models

Exactly like information revealed in table 1, covering-based models are applied massively in healthcare field nowadays. In 2004, DASKIN, M. S. and L. K. Dean published their paper where the location of health care facilities problem was researched. They identify three approaches with respect to accessibility, adaptability and availability to location models that have been applied for health care facilities. And the foundation of the three approaches mentioned above are set covering model, maximal covering model and P-median model [13]. Also, to address the question of locating healthcare facilities in a Brazilian city with respect to improve the effectiveness, ARNALDO and IARA do a research with the aid of P-median model, set and maximal covering models and P-center model [14]. LUCE BROTCORNE et al. review an evolution of ambulance location and relocation models proposed over past 30 years. Almost every model can be regarded as an extension of either set covering location model or maximal covering location models [15]. To optimize the locations of facilities of medical supplies for large-scale emergencies in Los Angeles area, HONGZHONG JIA with two others propose a general facility location model which can be cast as a covering model, a P-median model or a P-center model [16]. For maximizing the perinatal care accessibility in France, article presents a hierarchical location-allocation model that combines a maximum covering model and p-center model [17]. To address the demand uncertainty and medical supply insufficiency, authors propose models and solutions for determining the locations of medical supply facilities in response to large-scale emergencies [18]. The problem is formulated as a maximal covering problem [18]. With the purpose of making the healthcare level becomes more systematic and efficient, SHARIFF et al. develop a capacitated MCLP (CMCLP) based on the Maximal Covering Location Problem [19]. Furthermore, better locations of healthcare facilities are proposed for maximizing the population coverage [19].

Covering-based models use not only in healthcare field, but also military and/or security fields. MICHAEL C. in his paper seeks to find the optimal placement for one layer of the security net protecting nation's Intercontinental Ballistic Missile (ICBM) through utilizing three locating facility methods: maximum covering location model, p-centre model and p-median [20]. Similarly, with the aim of defense important national areas of interest in the U.S., John E. Bell et al. introduce location set covering problem to find the minimum number of alert sites, and then improves result according to p-median solution [21].

Covering-based models could also be applied to deal with complex mathematical problem. TATJANA, DUSAN and MILICA apply BCO (Bee colony optimization) to p-centre problem in the case of symmetric distance matrix, and propose variant of BCO based on an improvement concept (BCOi) [22]. In order to provide an overview of three advanced covering-based models (Gradual cover models, Cooperative cover model and Variable radius model), another paper of literature review is proposed by Berman and his co-workers [23].

Covering-based models contribute their strength in the public service field as well. ELIF, RAJAN et al. develop two separate models based on covering models contrapose a situation that demands occur from both nodes and paths [24]. Models in their paper are applied for capturing demand from both stationary cell phone users and cell phone users who are in moving vehicles [24]. For improving the geographical coverage area in some demands requirement, multiple fire trucks are need. And/or under the situation of large demand, ambulances may lead to unavailable. To address these two kinds of situations, RAJAN BATT and NARASIMH propose a new criterion for coverage based on the set covering location model and the maximal covering location model [25]. To address the lack of objective quantitative methods for police patrol area, a new method called backup covering location models based on the traditional maximal covering model for determining efficient spatial distributions is presented in KEVIN et al.'s article [26]. B. BLACK and B.M. BEAMON develop a variant model of maximal covering location model for determining the number and locations of distribution centres in a relief network, which integrates facility locations and inventory decisions under restrictions of both budgetary and capacity [27].

Some previous researches provide a great enlightenment for this paper particularly. For instance, REVELLE et al. published a paper that links the emergency facilities and costs together in 1970. Each demand point is specified by time or distance and required to be covered [28]. With the propose of improving the accessibility of post offices, an approach is presented in an article in 2015. Approach is a general method for determining the minimum number of postal units [29]. Hao Yu et al. in their paper put forward two concepts of accessibility and efficiency in printer distribution case study in a university for balancing customers' availability, responsiveness and efficiency [3].

2.2.2 Literature review based on median-based models

O. KARIV and S. L. HAKIM proves that the problem of finding a p-median of a network is an NP-hard problem even if the structure of network is simple [30].

Median-based models is applied broad in business field. Linda K. and Mark A. incorporate both fixed-charge model and p-median model for coordinating cost expense and customer responsiveness to address the locations of distribution centre (DC) in their case [31]. P-median and un-capacitated fixed charge facility location model are presented and compared in Radovan MADLENAK et al.'s research for optimizing the postal transportation network in minimizing average transport cost and furthermore the overall costs [32]. Analogously, with the aim of minimizing the sum of the setup cost and transportation cost, SITTIPONG DANTRAKUL together with two others introduce greedy algorithm, p-median algorithm and p-centre algorithm in their research [33]. A GIS-based method to calculate the spatial distribution of the potential demand is applied to ensure that the location of bike stations in relation to potential demand for the success of bike-sharing program [34]. LINDA K. et al. describe an optimal method for including inventory costs within a fixed-charge facility location model for distribution centres [35].

To ensure an equitable distribution of services is important in siting facilities, but sometimes capacity limitations at facilities should also be considered [36]. ALAN T. MURRAY introduces the Capacitated Regionally Constrained p-Median Problem together with regional requirements in a location-allocation framework, in addition to ensuring that maximum capacity limitations are maintained [36]. Under the help of p-median, p-centre and maximal covering location model, a location optimization model is developed by EBERLAN to optimally locate alert sites with minimum number, minimum aggregate network distance and minimized maximum distance given a range of aircraft launch times and speeds [37]. A review of strategic facility location provided by SUSAN and DASKIN in 1998. They focus on literatures which address the strategy of facility location problems by considering either stochastic or dynamic characteristics [38].

2.2.3 Literature review based on other models

ERHAN ERKUT gives a study repot about p-dispersion problem. The selected points in p-dispersion were considered as facility sites and the objective is to locate as 'dispersed' a set as possible [39]. Besides, he discusses related graph theoretical problems and proposes integer programming models in paper [39]. MICHAEL J. KUBY analyses both p-dispersion and maximum dispersion problem in 1987, and he gives an assumption in his article that p-dispersion problem may prove useful to find a starting distance for the series of covering problems [40].

2.3 Evolution of service facility location

The history of service facility location problem experiences several stages: the initial stages, the era of quantity, the era of humanity and the era of diversification [41].

2.3.1 The initial stages

In 1968, the concept of urban public service facility location was firstly proposed by MICHAEL B. TEITZ [42]. This concept differentiates between individual facilities location and public service facility location from basis according to G. DEVERTEUIL, which created a new frontier for service facility location problems [43]. TEITZ devoted himself to coordinate maximization of social benefits with the fairness of public service facility distribution. Besides, he stressed that the optimal layout of urban public service facilities need to take into account both efficiency and fairness [43]. Thus, the approach of quantification advocated by him has had a great impact on service facility location. The disadvantages of TEITZ's theory is lack of consideration of different service facilities' features and demander's preferences [44].

2.3.2 The era of quantity

Scholars introduced quantity methods and behavior analysis methods for studying service facility location problems in the 1970's, which made issues become more scientific and logical. And during that time, scholars developed various facility location models based on TIETZ's model according to factors of distance, accessibility and so on [45] [46].

In the era of quantity, fairness as well as efficiency were still the core of service facility location problems. To maximize the user accessibility with minimized number of facilities and costs, REVELLE et al. built a site selection model by applying operational research methods [47]. CHURCH and REVELLE gave expression to the idea of fairness by studying the maximum coverage problem with a pre-set coverage radius [48]. Another important feature of the quantity era was the widespread use of behaviour analysis. For instance, WOLPERT et al. studies the impact of human choice behaviour pattern on the distribution of public service facilities in their paper [49].

To introduce the quantitative method into service site selection problem made the characterization of fairness and efficiency became more accurate. Meanwhile, the utilization of behavioural analysis in service facility location increased the authenticity of location model, so that the connotation of the location variables became more abundant. However, researches were difficult to get rid of the dependence on quantity methods, and the consideration of location factors was still not rich enough.

2.3.3 The era of humanity

From the late 1970's until 1990's, scholars added the thoughts of humanism gradually into service facility location problems. The concept of human-oriented was magnified in facility location researches, so that human needs were appreciated.

Both WOLCH and DEAR studied the phenomenon of unfair distribution of urban public service facilities. They analysed the phenomenon of public service facilities' congestion in brownstone districts [50] [51]. A corresponding public service facility location model was established under the consideration of a wide range of location factors [52] [53].

2.3.4 The era of diversification

Since the mid of 1990's, academics started to research service facility location problems with wider perspective. The service facility location made a great stride forward into the era of diversification since then [41]. The theories and methods of service facility location have been pushed ahead after inheriting the achievements of previous studies until today, and became more comprehensive and systematic.

The concept of discrete hierarchical location introduced by Teixeira, J. C. et al. for service facility planning in their research. Features of this Model include: an accessibility maximization objective; several levels of demand and of facilities; a nested hierarchy of facilities; maximum and minimum capacity constraints and user-to-facility assignment constraints [54].

The problem of the location of public service facilities involves multifarious aspects in society, therefore the multi-objective location problem has been paid more and more attention. To address the facility location problem in tsunami prone areas, DOERNER et al. establish a multi-objective location model under the considerations of construction cost, total distance minimization and coverage distance in research [55]. In addition, a case study contraposed coastal school location in tsunami prone area in Sri Lanka was carried out by using NSGA-II algorithm [55]. Like the case introduced above, the multi objective location applies widely in emergency service facility locations.

2.4 Influence factors in service facility location

"Logistics centre location is a complex system that is affected by the economy, society and environment", said LV FENG and two others in their research when they attempted to establish a principle of Logistics Centre Location Evaluation Index System [56]. Throughout the history of development of service facility location problem, however I would like to replace the "environment" with "humanity". So that influence factors in service facility location become: Social factor, Economic factor and Humanistic factor.

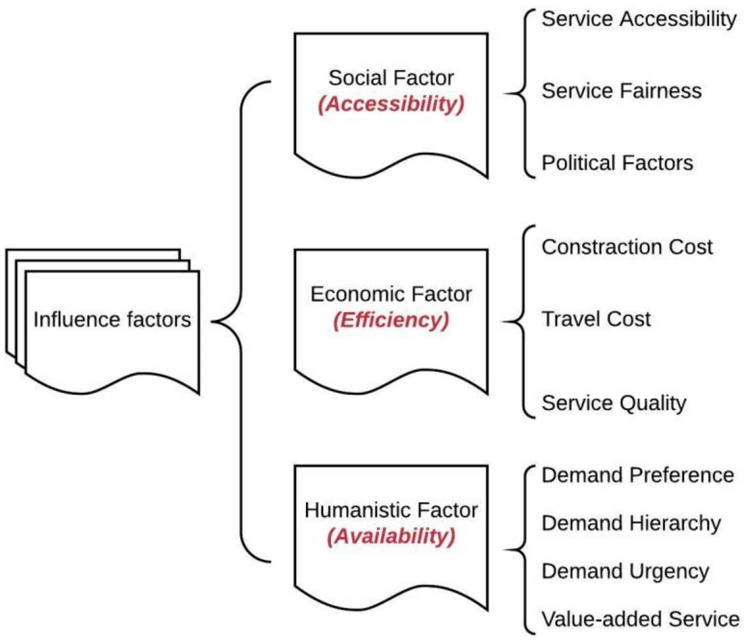


Figure 6 Influence factors differentiation

Figure 6 shows the influence factors which contains three specific subsets: social factor, economic factor and humanistic factor. Service accessibility, service fairness and political factors compose social factor that can be applied to estimate if services facilities with same function provide equally convenient service to each of their customers in spatial dimension. It is called the "accessibility" of service facilities. Finance factor maybe is the most important factor for service providers, and to coverage as many as their customer demands with limited number of service facilities is their ideal objective. It represents the "efficiency" of service facilities. Different customers have unlike personal preferences, and demands from the same customer can also be changed because of different situations. For instance, an ambulance might not be available when someone call for service because it is already occupying by another's demand. Availability is regarded as a short time unavailability of facilities, and how satisfy service facilities a diverse set of demands represents service facilities' availability.

Due to any factor has capability to affect a plan of service facility location, service facility location decision and/or model may be changed according to which one or more factors designer wants to add in. After reviewing a large number of previous contribution of facility location problems, a real case study carries out in this paper. Paper aims to do a location-based analysis of a postal service network in a city in northern Norway according to accessibility, efficiency and availability, which is rarely focused before. Then comparing the outcome with existing locations of postal service facilities in order to investigate whether the existing postal service performance could be improved and optimized in future. Three well-known location models are employed to help in this paper: Set covering location model, Maximal covering location model and P-median location model. Detailed description for all three location models are included in the next chapter.

3. Classic facility Location Models

In this chapter, the set covering location model, maximal covering location model and p-median location model is going to be presented one by one according to availability, efficiency and accessibility respectively.

Recalling section 2.2 that discrete location models were divided into three branches according to MARK S. DASKIN: Covering-based Models, Median-based models and Other Models. Both set covering model and maximal covering model belong to the branch of "covering-based models", and the reason is all three locations contain some critical coverage distance or time. A demand is fully satisfied if the nearest facility is within the critical distance, otherwise demand is not satisfied [12]. In addition, the satisfaction does not improve along with a demand is moving close to facility [12].

3.1 Set covering location problem (SCLP)

In some cases: for any emergency location in the event of an accident, the time or distance from the nearest emergency service facility to the emergency point must be stipulated, that is the time or distance must less than or equal to a specified value for reaching it in time. So now the question becomes to how to determine the location of emergency service facilities with minimized number of facilities for improving availability for customers.

In 1971, the set covering location model was first introduced by TOREGAS et al. with the propose of finding the minimum number (or cost) of facilities and their locations, so that each node-supplier must serve the facility with the specified maximum response time or distance, radius [28]. It must be noticed that all demand nodes are required to be covered by using set covering location model even if the number of facility to be located is minimized. Based on DASKIN [12], the mathematical model of demand weighted set covering location problem can be formulated as follows:

(SCLP)

MINIMIZE $$\sum_{j \in J} c_j x_j \qquad (1)$$

SUBJECT TO: $$\sum_{j \in N_i} x_j \geq 1 \quad \forall i \in I \qquad (2)$$

$$x_j \in \{0,1\} \quad \forall j \in J \qquad (3)$$

Where

c_j = Cost of construction

I = Denotes the set of demand nodes indexed by i

J = Denotes the set of candidate facility locations, indexed by j

d_{ij}= Distance between demand node i and candidate facility j

D_c = Distance coverage

$N_i = \{j | d_{ij} \leq D_c\}$ = denotes the set of all candidate locations that can cover demand point i and the following decision variable

$$x_j = \begin{cases} 1, & if\ we\ locate\ at\ site\ j \\ 0, & if\ not \end{cases}$$

In the set covering location model, the objective of Eq. (1) minimizes the quantity of located facilities in service network. Eq. (2) guarantees that each demand node is covered by at least one facility. And Eq. (3) enforces 'yes' or 'no' nature of the siting decision.

Moreover, single facility is generally not able to meet the needs in some cases if a major disaster or accident occurs. Thus, it may be specified the number of facilities that must be reached when an emergency occurs. Then the constrain (2) might become to $\sum_{j \in N_i} x_j \geq b, where\ b \geq 2$.

3.2 Maximal covering location problem (MCLP)

The precondition of finding minimum number of facilities and their locations through set covering location method is that all of demand points must be covered. In another word, facility location designers are no need to worry about the construction investment too much. However, a budget does exist for the most of cases [12]. When the decision maker does not have enough resources to meet all needs, a workaround is he or she needs. For improving the efficiency of facility usage, decision maker must to locate a fixed number of facilities and the specified maximum response time or desired service distance. In such a way, as few people as possible lie outside the line [57].

Under this circumstance, CHURCH and REVELLE proposed and formulated the original maximal covering location problem in 1974 [48]. Maximal covering location problem refers to locate limited number (P) of facilities to maximize the number of covered demands. This model differentiates between big and small demands and allows some demand needs to be uncovered if the number of facilities needed to cover all demand nodes exceeds P. The mathematical model of maximal covering location problem can be formulated as follows:

(MCLP)

MAXIMIZE

$$\sum_{i=1}^{n}\sum_{j=1}^{n} w_i s_{ij} x_{ij} \tag{4}$$

SUBJECT TO:

$$\sum_{i=1}^{n} x_{ij} = 1 \qquad \forall i \leq I \tag{5}$$

$$\sum_{i=1}^{n} y_i = P \tag{6}$$

$$x_{ij} \leq y_j \quad \forall i \in I; j \in J \tag{7}$$

$$x_{ij} = \{0,1\} \qquad \forall i, j \tag{8}$$

$$y_j = \{0,1\} \qquad \forall \in J \tag{9}$$

Where

n = Total number of demand points

w_i = Demand at point i

d_{ij} = Travel distance between point i and j

x_{ij} = 1, point is covered by facility that located at point j

= 0, otherwise

y_j = 1, if facility is located at node j

= 0, otherwise

P = Number of facility to be located

d_s = Distance beyond which a demand area is considered uncovered

s_{ij} = 1, if $d_{ij} \leq d_s$

= 0, otherwise

In the maximal covering location model, the objective of Eq. (4) maximizes the overall weighted customer demands within the maximum coverage distance, ds. Eq. (5) ensures that each demand point is served by exactly one facility. Eq. (6) rules that there are exactly P facilities located. Constrain (7) guarantees that each demand point can be covered. Due to maximal covering location problem is an integer programming problem, Eq. (8) and Eq. (9) make sure that integer condition is provided.

The maximal location problem seeks the locations of p facilities so that the total demand–weight distance between demand nodes and the facilities to which they are assigned is maximized [38].

3.3 P-median problem

To analyse the accessibility of service facility in service network, p-median the classic mathematical model which cannot be missed. According to Mark S. DASKIN's theory, the p-median is under the branch of median-based models in discrete location models. Thus, the goal of p-median mathematical model is to minimize the weighted demand average distance between a demand site and facility [12]. P-median model was proposed by S. L. HAKIMI for finding optimum location of switching centre in communication network and a police station in a highway system in 1960's [58] [59]. The mathematical model of p-median location problem can be formulated as follows:

(P-MEDIAN)

MINIMIZE

$$\sum_{j \in J}^{n} \sum_{i \in I}^{n} h_i d_{ij} Y_{ij} \tag{10}$$

SUBJECT TO:

$$\sum_{j \in J} Y_{ij} = 1 \qquad \forall i \leq I \tag{11}$$

$$\sum_{j \in J} x_j = P \tag{12}$$

$$Y_{ij} \leq x_j \qquad \forall i \in I; j \in J \tag{13}$$

$$x_j = \{0,1\} \qquad \forall j \in J \tag{14}$$

$$Y_{ij} = \{0,1\} \qquad \forall i \in I;\ \forall j \in J \tag{15}$$

$$0 \leq Y_{ij} \leq 1 \qquad \forall i \in I; \forall j \in J \tag{16}$$

Where

n = Total number of demand points

h_i = Demand at point i

d_{ij} = Travel distance between customer point i and candidate site j

Y_{ij} = 1, if demand node I is assigned to a facility at candidate site j

= 0, otherwise

x_j = 1, if facility is located at candidate site j

= 0, otherwise

P = Number of facility to be located

In the p-median location model, the objective of Eq. (10) minimizes the demand-weighted total distance between demand sites and service facilities. Eq. (11) makes sure that every demand node is assigned while Eq. (13) limits assignment to open or selected sites. Eq. (12) claims that there are P facilities are going to be located. Eq. (14) and Eq. (15) make sure that integer condition is provided. Eq. (16) can be transformed from Eq. (15) since every demand node is going to be assigned to the closest open site automatically in any possible solutions.

3.4 Facility location model comparison

Table 2 – Comparison of different discrete location models.

Facility location model applied	*Objective of model*	*Applied to improve*	*Specified Facility Number?*	*100% Coverage always?*	*Specified Coverage Distance?*
SCLP	Finding minimum number of service facilities and locations	Availability	No	Yes	Yes
MCLP	Maximizing the coverage of customer demands	Efficiency	Yes	No	Yes
P-median	Minimizing overall weighted distance between demand points and service facilities	Accessibility	Yes	No	No

4. Case study

Set covering location model, maximal covering location model and p-median model of facility location models were introduced in chapter 3 for evaluating the performance of a postal service network according to availability, efficiency and accessibility respectively. However, the optimal solution should be gained through both horizontal comparison within one facility location model and vertical comparison among different facility location models.

Before starting the real-world case (postal service network), three simplified case studies carry out in this chapter with respect to three different facility location models mentioned before. The main purpose of these case studies is to get familiar and master the software operational approach corresponding to mathematical modelling. Furthermore, to initiate and optimize the result analysis with a simple facility location structure.

In 2010, MARK S. DASKIN published a simple p-median example with topological graph to illustrate the method of solving simple p-median problem by utilizing spreadsheets. Besides, Lee, W. C. et al. propose a spreadsheet approach as well in their study for three well-known facility location problems: the p-median problem (PMP), capacitated p-median (CPMP), and maximal covering location problem (MCLP) [60]. Both papers enlightened the subsequent work in this article.

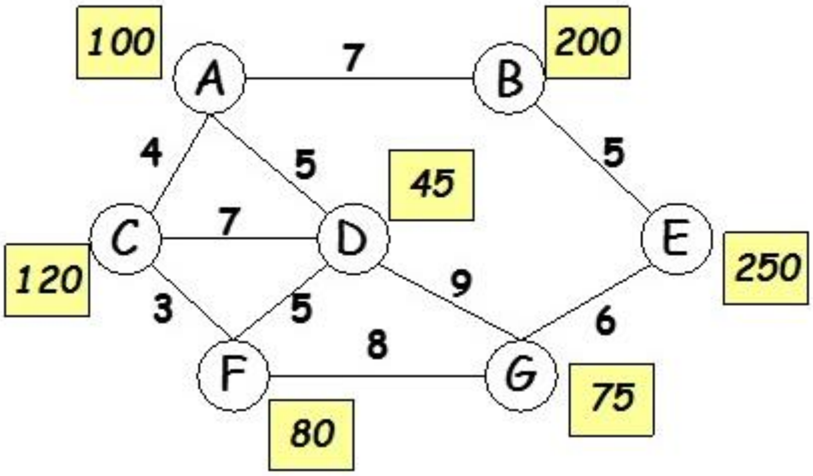


Figure 7 Connection between buildings with demands and distances

Figure 7 which provided by DASKIN contains 7 demand point as well as potential facility locations. Each demand point in the figure is marked with a unique demand weight and distance between any of two points is also given in this picture. This classic topological graph is going to be applied in all following case studies hereafter.

4.1 Software introduction

The Solver™ add-in to Excel® is the software that applied in this paper. It is an Add-ins which embedded within office Excel. By Solver™ add-in to Excel®, users can find the maximum or minimum value of a formula in a cell on the worksheet. Through adjusting values of a set of cells directly or indirectly, the Solver™ add-in to Excel® can help users to find final desired results which formulated in target worksheet. In the process of mathematical model creation, user can also set constraints to variable value cells in the Solver™ add-in to Excel®. The limitation of the Solver™ add-in to Excel® for nonlinear problem are up to 200 decision variables and 100 constraints in addition to bounds on the variables. The advantages of applying the Solver™ add-in to Excel® are: wide availability, friendly interface, straight forward structures, coding free, effective and easy to update. In addition, it can generate good solutions, including conditions descriptions of location and allocation, within a reasonable process time [60].

4.2 A case study of set covering location problem

Case description: Several kiosks are opening in a university camp for serving students, and the camp's map is represented in figure 7 shown above. As figure 7 illustrates, seven buildings counted from A to G are picked in this figure as a potential location for the kiosk and some connections in between buildings are also described. The future kiosk owner wants to sever all seven buildings at the same time with minimized cost and to ensure the availability for students in camp. To explain the connections, two buildings A and B for instance are connected if one student in building A can walk to building B and go back to building A within a limited time interval or the distance between A and B is no more than a certain value (for example: four minutes or 100 meters). By following this thought, connections between buildings in figure 7 are explained. Opening a kiosk in one building will satisfy the demand of buildings that are connected to (or in the neighbourhood of) this corresponding building. And the objective of this case study is to find a minimum number of kiosks to be opened such that all students can possible buy snakes, drinks and/or coffee during the time break and without being late for the class.

The Solver™ add-in to Excel® is used to arrive at optimal or near optimal solutions for both number and placement of this kiosk problem.

4.2.1 Brief review of set covering problem

Before starting the case study, a simple and straightforward review of set covering problem description is given here. Assuming there is a set of n elements represented by i $= \{1,2,3,4 \ldots n\}$, and a set of j subsets of i represented by j $= \{s_1, s_2, s_3 \ldots s_m\}$. The goal by using set covering location model is to choose the minimum number of j subsets such that all elements in i are to be covered.

4.2.2 Mathematical modelling experimentation on spreadsheet

First and foremost, the subsets and elements belongs to it need to be define. Students have to be able to travel during the break without late for the class, which means a coverage distance needs to be find based on figure 7. Theoretically, one can choose any reasonable distance value. But in the set covering location model, all demand points are required to be covered. Thus, the coverage distance choices according to figure 7 are: 6 or 7 or 8 or 9. The value which under 6 cannot provide full coverage and the value over 9 are meaningless in this case.

Set Distance Coverage =6	
Subsets	**Covers**
A	A,C,D
B	B,E
C	A,C,F
D	A,D,F
E	B,E,G
F	C,D,F
G	E,G

Figure 8 Coverage area corresponding to subset respectively

Figure 8 shows the subsets and elements belong to under the precondition of distance coverage distance equal to 6. Explanation of this relationship is based on figure 7. When it comes to building A, the designer need to check which building is connecting to it within the distance limitation equal to 6. So, building A is connecting to C, D and A itself because student can shop within the same building without going to somewhere else. That means, opening a kiosk in building A can cover building A, building C and building D because of the connections. Similarly, for building B which is connected to building E and itself. By following this method, with coverage limitation equal to 6, all connections between buildings according to figure 7 are found and showed in figure 8. Different coverage distances can change the subsets' coverage which shown in figure 9 below:

Set Distance Coverage =5		Set Distance Coverage =6		Set Distance Coverage =7	
Subsets	**Covers**	**Subsets**	**Covers**	**Subsets**	**Covers**
A	A,C,D	A	A,C,D	A	A,B,C,D
B	B,E	B	B,E	B	A,B,E
C	A,C,F	C	A,C,F	C	A,C,D,F
D	A,D,F	D	A,D,F	D	A,C,D,F
E	B,E	E	B,E,G	E	B,E,G
F	C,D,F	F	C,D,F	F	C,D,F
G	Noen	G	E,G	G	E,G

Set Distance Coverage =8		Set Distance Coverage =9		Set Distance Coverage =10	
Subsets	**Covers**	**Subsets**	**Covers**	**Subsets**	**Covers**
A	A,B,C,D	A	A,B,C,D	A	A,B,C,D
B	A,B,E	B	A,B,E	B	A,B,E
C	A,C,D,F	C	A,C,D,F	C	A,C,D,F
D	A,C,D,F	D	A,C,D,F,G	D	A,C,D,F,G
E	B,E,G	E	B,E,G	E	B,E,G
F	C,D,F,G	F	C,D,F,G	F	C,D,F,G
G	E,F,G	G	D,E,F,G	G	D,E,F,G

Figure 9 Different building coverage based on different coverage distance value

As shown in figure 9, the building coverage of each building is increasing from distance coverage equal to 6 until distance equal to 9. Building G cannot be covered by any of seven building with distance coverage equal to 5, which unqualified in set covering location model. Since when distance limitation equal to 9, all building connections described in figure 7 are satisfied, therefore it is meaningless by setting distance coverage equal to 10. So, there are seven subsets, index on j: A, B, C …G. And the decision variables xj = 1, if a kiosk is opened in building j, and 0 otherwise. Parameter dij describes the distance between demand node i and candidate site j. Thus, dij =1, if kiosk opened in building j can cover building i. In addition, to mention the constrain here is every building must be served by at least one kiosk for improving availability. Figure 10 below shows the demand and decision variable matrixes for the kiosk plan, therein, decision variables are specified to be binary number (1 or 0).

Cost Routes			Decision Variables	
A	100		A	0
B	200		B	0
C	120		C	0
D	45		D	0
E	250		E	0
F	80		F	0
G	75		G	0

Figure 10 Customer demands and Decision variables.

To formulate the kiosk plan applied by set covering location model is Minimize A+B+C+D+E+F+G. Here comes to the constrains. For each building, there is a constrains, and constrains can be changed based on varying coverage distance. For instance, the designer set coverage distance equal to 6 in figure 8. Under this circumstance, the constrains for buildings are subjected to:

A + C + D >= 1 (Building A)

B + E >= 1 (Building B)

A + C + F >= 1 (Building C)

A + D + F >= 1 (Building D)

B + E + G >= 1 (Building E)

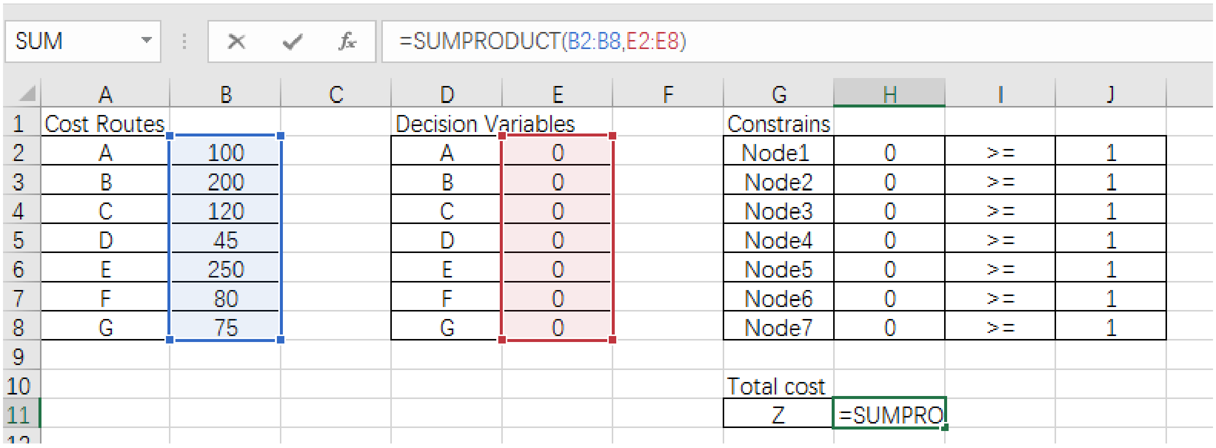
C + D + F >= 1 (Building F)

E + G >= 1 (Building G)

$x_j \in \{0,1\} \quad \forall j$

Recalling the formula (1) of demand weighted set covering location model, and the total cost with minimum number of facilities can be represented by using SUMPRODUCT function in Excel. SUMPRODUCT multiplies corresponding members in given arrays and returns the sum of those products. In addition, the SUMPRODUCT function only deal with arrays with same size.

Then, the formula (1) is represented in such way: Minimal cost Z = SUMPRODUCT (Cost Route Matrix · Decision Variable Matrix) shown in figure 11 below together with constrains' table. Decision variable was started with a null matrix (all entries zero) And figure 12 shows the solver settings for this experimentation.



SUM | =SUMPRODUCT(B2:B8,E2:E8)

	A	B	C	D	E	F	G	H	I	J
1	Cost Routes			Decision Variables			Constrains			
2	A	100		A	0		Node1	0	>=	1
3	B	200		B	0		Node2	0	>=	1
4	C	120		C	0		Node3	0	>=	1
5	D	45		D	0		Node4	0	>=	1
6	E	250		E	0		Node5	0	>=	1
7	F	80		F	0		Node6	0	>=	1
8	G	75		G	0		Node7	0	>=	1
9										
10							Total cost			
11							Z	=SUMPRO		

Figure 11 Illustration of SCLP mathematical model example in Spreadsheet

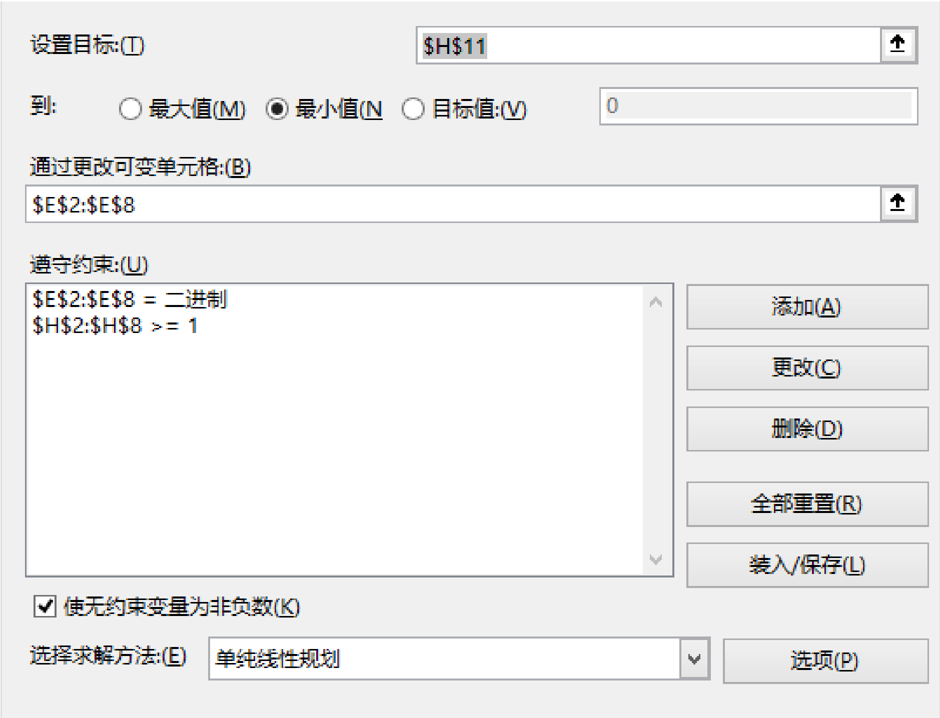


Figure 12 Solver setting example of SCLP

4.2.3 Results comparison and analysis

Finally, the optimal solution shown in figure 13 is calculated with respect to coverage distance equal to 6. Under the help of Standard LP/Quadratic Solver engine provided by Excel.

Analysing the result shown in figure 13 together with figure 9. Under the precondition of coverage distance was equal to 6, there are at least three kiosks opened at building D, building E and building F respectively in order to satisfy that each demand point is covered by at least one service facility. In another word, all 7 buildings can be served in the university camp with minimum number of kiosks (cost).

Cost Routes			Decision Variables			Constrains			
A	100		A	0		Node1	1	>=	1
B	200		B	0		Node2	1	>=	1
C	120		C	0		Node3	1	>=	1
D	45		D	1		Node4	2	>=	1
E	250		E	1		Node5	1	>=	1
F	80		F	1		Node6	2	>=	1
G	75		G	0		Node7	1	>=	1
						Total cost			
						Z	375		

Figure 13 Number and location of kiosk in camp with respect to coverage equal to 6

However, the result changes along with the different value of building coverage, which explained in figure 9. For analysing and comparing all situation, table 3 is proposed with respect to various coverage distance as follows.

Table 3 – Comparison of SCLP based on varying coverage distance in kiosk case (constrains>=1)

Coverage distance (D_c)	Number of opened kiosk	Locations	Total Cost
6	3	D, E, F	375
7	3	A, D, G	220
8	2	A, G	175
9	2	A, G	175

A curve graph based on table 3 is given below in figure 14, which represents the relationship between the cost of investment and number of kiosk opened under the precondition of full coverage. Although the quantity of date collection is limited in this kiosk case experimentation, the character of set covering location model can also be reflected generally. Which is the cost of investment is decreasing along with the coverage distance increases. Because longer coverage distance increases service possibility and the service radius which leads to fewer service building required.

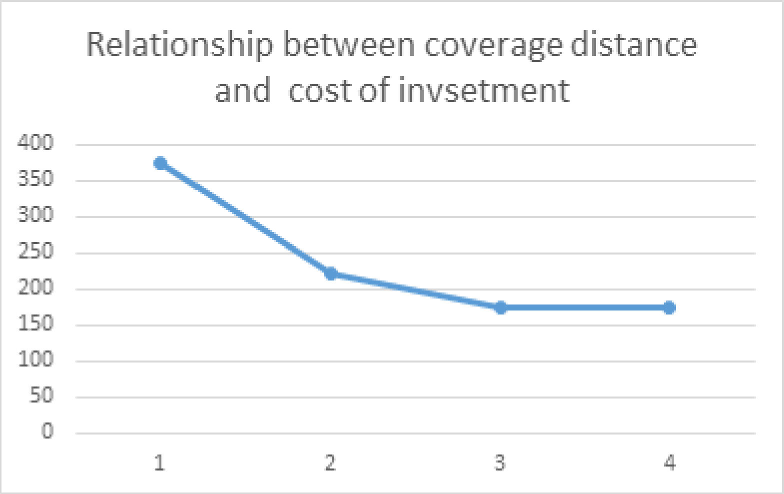


Figure 14 Relationship between investment cost and coverage distance

As it mentioned before, single facility is generally not able to meet the needs in some cases if a major disaster or accident occurs. So, what if changing the constrains to make sure that every building must be served by at least two kiosks. So that the availability can be improved further. Result of this special case study shown in Table 4 as follows.

Table 4 – Comparison of SCLP based on varying coverage distance in kiosk case (constrains >=2)

Coverage distance (D_c)	Number of opened kiosk	Locations	Total Cost
6	6	A, B, D, E, F, G	750
7	5	A, D, E, F, G	550
8	4	A, B, F, G	455
9	4	A, B, D, G	420

After modifying constrains from (>=1) to (>=2), different quantity and locations of opened kiosks are shown in table 4 with respect to different values of coverage distance. It's obviously that for improving the service availability of kiosk, the number of opened kiosks is increasing dramatically along with the investment cost as well. Therefore, it is not recommended to set the constrain with extremely high availability unless under the situation of emergency such as a major disaster or an accident.

4.3 A case study of maximal covering location problem

Case description: like the previous case study of set covering location problem. Several kiosks are going to open in a university camp for serving students, and the camp's map is represented in figure 7. As figure 7 illustrates, seven buildings counted from A to G are picked in this figure as a potential location for the kiosk and some connections in between buildings are also described.

Due to economic reason, the future kiosk owner wants to open as few number as possible kiosks without losing too much coverage of customer demands. A coverage distance is also needed to be considered in this case. To explain the connections, two buildings A and B for instance are connected if one student in building A can walk to building B and go back to building A within a limited time interval or the distance between A and B is no more than a certain value (for example: four minutes or 100 meters). Opening a kiosk in one building will satisfy the demand of buildings that are connected to (or in the neighbourhood of) this corresponding building.

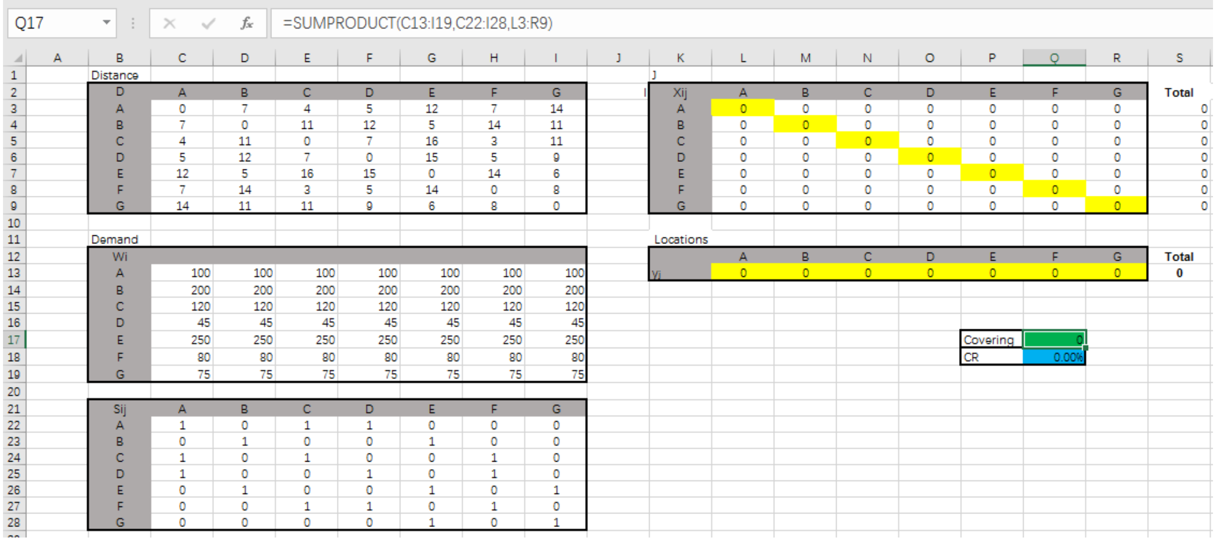
The Solver™ add-in to Excel® is used to arrive at optimal or near optimal solutions for both number and placement of this kiosk problem.

4.3.1 Brief review of maximal covering location problem

Assuming there is a set of n elements represented by $\mathrm{i} = \{1,2,3,4 \dots n\}$, and a set of j subsets of i represented by $\mathrm{j} = \{s_1, s_2, s_3 \dots s_m\}$. The mathematical model of maximal covering location problem is formulated between (4) and (9). And the objective of using MCLP in this case study is to maximize the coverage of customer demands within a limited number of kiosk opened.

4.3.2 Mathematical modelling experimentation on spreadsheet

According to the case description and the relationship of building connections, an experimentation on the spreadsheet is done based on mathematical model of maximal covering location problem which is explained in section 3.2. Illustration of MCLP mathematical model experimentation in Spreadsheet shown in figure 15.



Q17 =SUMPRODUCT(C13:I19,C22:I28,L3:R9)

Distance

D	A	B	C	D	E	F	G
A	0	7	4	5	12	7	14
B	7	0	11	12	5	14	11
C	4	11	0	7	16	3	11
D	5	12	7	0	15	5	9
E	12	5	16	15	0	14	6
F	7	14	3	5	14	0	8
G	14	11	11	9	6	8	0

Demand

Wi							
A	100	100	100	100	100	100	100
B	200	200	200	200	200	200	200
C	120	120	120	120	120	120	120
D	45	45	45	45	45	45	45
E	250	250	250	250	250	250	250
F	80	80	80	80	80	80	80
G	75	75	75	75	75	75	75

Sij	A	B	C	D	E	F	G
A	1	0	1	1	0	0	0
B	0	1	0	0	1	0	0
C	1	0	1	0	0	1	0
D	1	0	0	1	0	1	0
E	0	1	0	0	1	0	1
F	0	0	1	1	0	1	0
G	0	0	0	0	1	0	1

J

Xij	A	B	C	D	E	F	G	Total
A	0	0	0	0	0	0	0	0
B	0	0	0	0	0	0	0	0
C	0	0	0	0	0	0	0	0
D	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0	0
F	0	0	0	0	0	0	0	0
G	0	0	0	0	0	0	0	0

Locations

	A	B	C	D	E	F	G	Total
yi	0	0	0	0	0	0	0	0

Covering	0
CR	0.00%

Figure 15 Illustration of MCLP mathematical model example in Spreadsheet

Matrixes are made straight forward corresponding to the objective function of maximal covering location model in equation (4). Because of SUMPRODUCT function only deal with arrays with the same size, therefore, demand matrix Wi[n x n] was expended from Wi[n x 1]. The maximal coverage distance ds should also be set in maximal covering location problem. Let ds equal to 6 as an example, the value of Sij in figure 15 equal to 1 if distance between kiosk and building no longer than 6; otherwise Sij = 0. Besides, matrix Xij is the matrix of decision variables and Cell S3 = SUM (L3:R3) applied to (S4:S9). Matrix yi =1 if kiosk is opened in the building; otherwise yi = 0. Cells with yellow color are set to be same within a vertical line, for instance L3 = L13. Constrain setting in solver shown in figure 16, and the one can set the number of kiosk by changing S13 in solver setting.

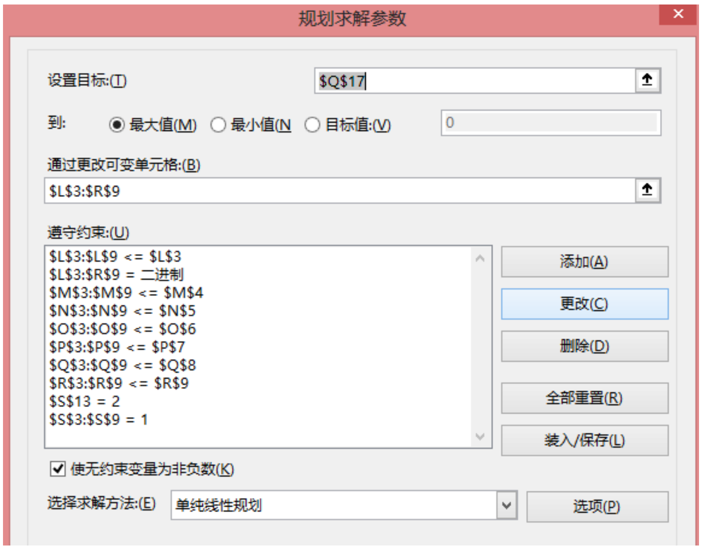


Figure 16 Solver setting example of MCLP

4.3.3 Results comparison and analysis

In maximal covering location model, the objective function is looking for to realize the maximal demand coverage with a limited number of facilities. Thus, an imperfect coverage situation is permitted in this case. First of all, to run the solver after setting maximal coverage distance equal to 6 and wanted building numbers equal to 2. Then the outcome shows in figure 17.

J

I U	A	B	C	D	E	F	G	Total
A	0	0	1	0	0	0	0	1
B	0	0	0	0	1	0	0	1
C	0	0	1	0	0	0	0	1
D	0	0	1	0	0	0	0	1
E	0	0	0	0	1	0	0	1
F	0	0	1	0	0	0	0	1
G	0	0	0	0	1	0	0	1

Locations

	A	B	C	D	E	F	G	Total
yj	0	0	1	0	1	0	0	2

Covering	825
CO/totde	94.83%

Figure 17 Outcome of MCLP with respect to d_s = 6 and number facility equal to 2

To keep the maximal coverage equal to 6, outcomes with respect to different number of wanted facilities is presented as follows:

Table 5 – Relationship between wanted facility numbers and covering under the condition of d_s = 6 in MCLP

Coverage distance (d_s)	**Number of wanted facilities**	**Locations**	**Covering**	**Covering / Total demand (870)**
6	1	E	525	60.34%
6	2	C, E	825	94.83%
6	3	A, C, E	870	100%
6	4	A, B, C, G	870	100%

Table 6 – Relationship between wanted facility numbers and covering under the condition of d_s = 5 in MCLP

Coverage distance (d_s)	**Number of wanted facilities**	**Locations**	**Covering**	**Covering / Total demand (870)**
5	1	E	450	51.2%
5	2	B, C	750	86.2%
5	3	A, B, F	795	91.38%
5	4	A, B, C, G	870	100%

Comparing results from table 5 with from table 6, it shows that the service provider has to build more facilities to get the same level of demand coverage before it becomes 100% if the coverage distance decrease.

In previous set covering location model analysis, in order to get 100% coverage, the minimum number of kiosk opened was 3 with respect to ds= 6 or 7, and minimum number of kiosk opened was 2 with respect to ds=8 or 9. In this case, the service provider who is going to apply maximal covering location model will not open more than 3 kiosks. Therefore, an analysis based on this idea shown in table 7.

Table 7 – Covering comparison results between same number of facilities (j<=3) and different d_s

Coverage distance (d_s)	Number of wanted facilities	Locations	Covering	Covering / Total demand (870)
6	1	E	525	60.34%
7	1	B	550	63.22%
8	1	B	550	63.22%
9	1	B	550	63.22%
6	2	C, E	825	94.83%
7	2	A, E	870	100%
8	2	A, E	870	100%
9	2	A, E	870	100%
6	3	A, C, E	870	100%
7	3	A, B, G	870	100%
8	3	A, B, G	870	100%
9	3	A, B, G	870	100%

Although the quantity of date collection is limited in this kiosk case study, it still can be inferred based on table 7 that is with extremely low number of service facilities, the demand coverage will not increase along with the coverage distance getting greater.

Table 8 – Covering comparison results between SCLP and MCLP

Coverage distance (D_s)	Number of opened kiosk	Locations	Covering	Model types
6	3	D, E, F	100%	SCLP
6	3	A, C, E	100%	MCLP
6	2	C, E	94.83%	MCLP

Table 8 shows that the total customer demands could be reached by locating 3 kiosks in the camp for both set covering location model and maximal covering location model. However, to open two kiosks in building C and E instead for opening 3 kiosks, which seems to be a great idea if the service provider has a limitation on budget. Due to uncovered condition is not allowed in set covering location model, the maximal covering location model can provide more economic and efficient solution.

4.4 A case study of p-median problem

The case description is similar to the previous one. Someone is planning to open several kiosks in a university camp to provide service to students. The camp's map is shown in figure 7. As figure 7 illustrates, seven buildings (from A to G) are picked in this figure as a potential location for the kiosk.

The owner of kiosk wants to open certain number of kiosks in a way that the overall or average travel distance from customer demand points to the kiosk is minimized. So that the accessibility of kiosks is maximized. Little different from the set covering location problem and maximal location covering problem, designer does not need to consider about the coverage distance in p-median problem. But the number of opened kiosk must be defined.

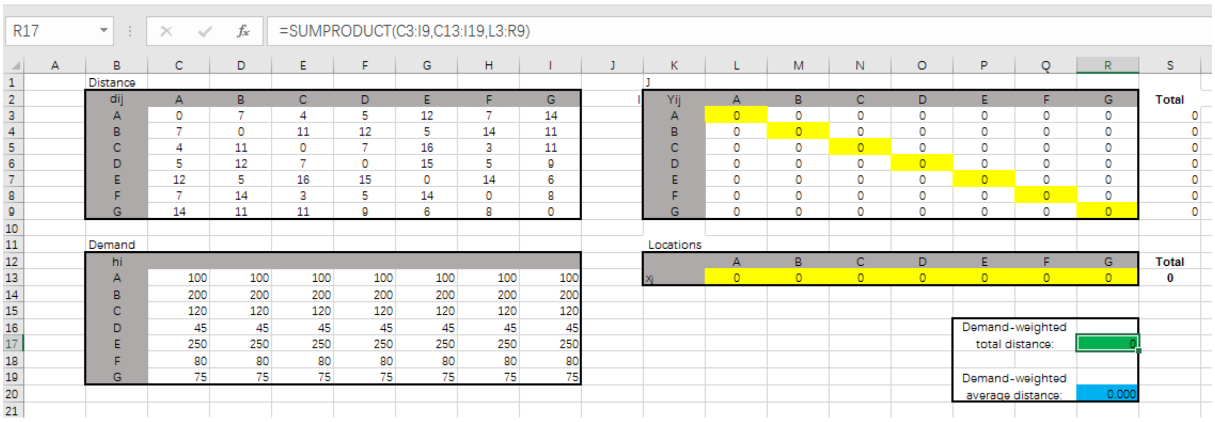
The Solver™ add-in to Excel® is used to arrive at optimal or near optimal solutions for both number and placement of this kiosk problem.

4.4.1 Brief review of maximal covering location problem

Assuming there is a set of n elements represented by $\mathrm{i} = \{1,2,3,4 \ldots n\}$, and a set of j subsets of i represented by $\mathrm{j} = \{s_1, s_2, s_3 \ldots s_m\}$. The mathematical model of p-median problem is formulated between (10) and (15). And the objective of using p-median model in this case study is to minimize the demand-weighted total distance, for improving kiosk's accessibility

4.4.2 Mathematical modelling experimentation on spreadsheet

According to the case description and the relationship of building connections, an experimentation on the spreadsheet is done based on mathematical model of maximal covering location problem which is explained in section 3.3. Illustration of p-median mathematical model experimentation in Spreadsheet shown in figure 18.


R17 =SUMPRODUCT(C3:I9,C13:I19,L3:R9)

Distance

dij	A	B	C	D	E	F	G
A	0	7	4	5	12	7	14
B	7	0	11	12	5	14	11
C	4	11	0	7	16	3	11
D	5	12	7	0	15	5	9
E	12	5	16	15	0	14	6
F	7	14	3	5	14	0	8
G	14	11	11	9	6	8	0

Demand

hi							
A	100	100	100	100	100	100	100
B	200	200	200	200	200	200	200
C	120	120	120	120	120	120	120
D	45	45	45	45	45	45	45
E	250	250	250	250	250	250	250
F	80	80	80	80	80	80	80
G	75	75	75	75	75	75	75

J / I

Yij	A	B	C	D	E	F	G	Total
A	0	0	0	0	0	0	0	0
B	0	0	0	0	0	0	0	0
C	0	0	0	0	0	0	0	0
D	0	0	0	0	0	0	0	0
E	0	0	0	0	0	0	0	0
F	0	0	0	0	0	0	0	0
G	0	0	0	0	0	0	0	0

Locations

	A	B	C	D	E	F	G	Total
xj	0	0	0	0	0	0	0	0

Demand-weighted total distance:	0
Demand-weighted average distance:	0.000

Figure 18 Illustration of p-median mathematical model example in Spreadsheet

Matrixes are made straight forward corresponding to the objective function of maximal covering location model in equation (10). Because of SUMPRODUCT function only deal with arrays with the same size, therefore, demand matrix Wi[n x n] was expended from Wi[n x 1]. Constrain setting in solver shown in figure 19, and one can set the number of kiosk by changing S13 in solver setting.

Figure 19 Solver setting example of p-median

4.4.3 Results comparison and analysis

In p-median model, the objective function is looking for to minimize the overall weighted customer distance with a given number of facilities. To illustrate the modelling process of p-median problem by applying Solver, set opened kiosk equal to 1 by changing 13 = 1 in figure 19. The outcome shown in figure 20

Distance

dij	A	B	C	D	E	F	G
A	0	7	4	5	12	7	14
B	7	0	11	12	5	14	11
C	4	11	0	7	16	3	11
D	5	12	7	0	15	5	9
E	12	5	16	15	0	14	6
F	7	14	3	5	14	0	8
G	14	11	11	9	6	8	0

Demand

hi							
A	100	100	100	100	100	100	100
B	200	200	200	200	200	200	200
C	120	120	120	120	120	120	120
D	45	45	45	45	45	45	45
E	250	250	250	250	250	250	250
F	80	80	80	80	80	80	80
G	75	75	75	75	75	75	75

J

Yij	A	B	C	D	E	F	G	Total
A	0	1	0	0	0	0	0	1
B	0	1	0	0	0	0	0	1
C	0	1	0	0	0	0	0	1
D	0	1	0	0	0	0	0	1
E	0	1	0	0	0	0	0	1
F	0	1	0	0	0	0	0	1
G	0	1	0	0	0	0	0	1

Locations

	A	B	C	D	E	F	G	Total
xj	0	1	0	0	0	0	0	1

Demand-weighted total distance:	5755
Demand-weighted average distance:	6.615

Figure 20 Outcome of p-median method with respect to kiosk number equal to 1

By using this method, different outcomes are calculated and showed in table 9 below, and the relationship between facility numbers and demand-weighted average distance according to table 9 shown in figure 21. It denotes that the more kiosks open, the more accessible for service network of kiosks.

Table 9 – Total/avg. demand-weighted distance are decreasing along with P increases

Number of given facilities	Building Locations	Demand-weight total distance	Demand-weighted average distance (Demand-weighted total distance/tot. demand)
1	B	5575	6.615
2	C, E	2405	2.764
3	B, C, E	1405	1.615
4	A, B, C, E	915	1.052
5	A, B, C, E, G	465	0.534
6	A, B, C, E, F, G	225	0.259
7	A, B, C, D, E, F, G	0	0

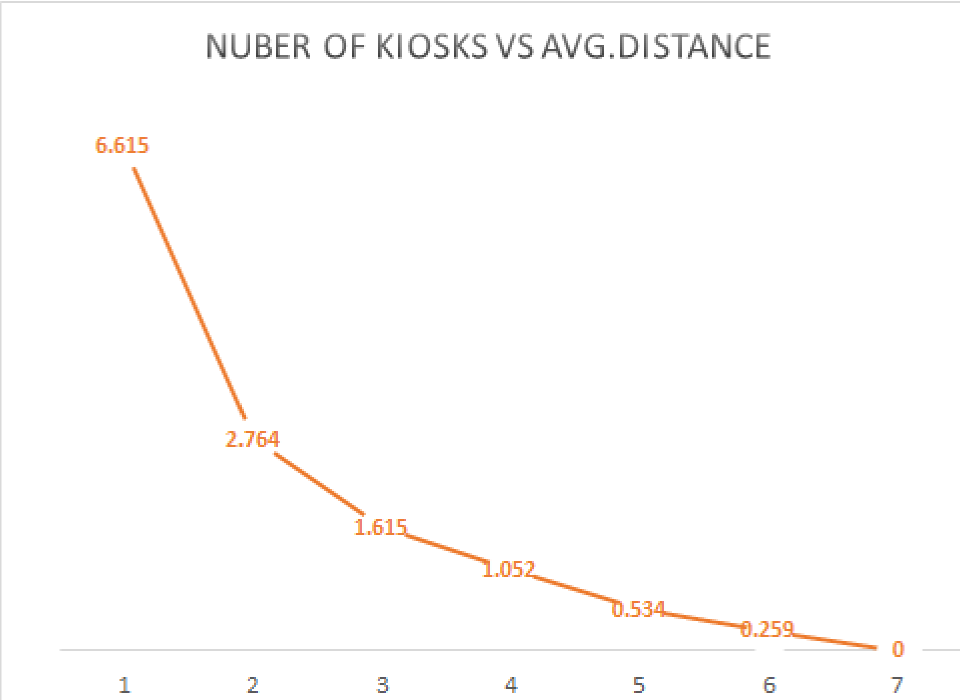


Figure 21 Demand-weighted average distance with respect to number of facilities

5. Research on the performance of a postal service network – A real-world case study

A real-world case study is proposed in this chapter in order to present a deep inside of location-based modelling approach. The objective of this chapter is to do a location-based analysis for existing postal service facilities with respect to availability, efficiency and accessibility in a city in northern Norway and evaluate the performance of the existing postal service network.

5.1 City Overview

NARVIK is a city in the province of Norland in northern Norway. According to Google's database in 2012, 18, 473 residents are living in this city. NARVIK is an ice-free port because the North Atlantic warm current flows through. In this city, people can experience both Polar night and daylight phenomenon due to city is in the north of the Arctic Circle. And the most important features of NARVIK city are to go skiing and/or to enjoy aurora during winter time, which attracts thousands and thousands of tourists from all over the world.

5.2 Status of postal service in the city

POSTEN Norway shutdown the most number of original post offices continuously in nationwide after 2013, and turned to partner with local supermarket instead. For example, POSTEN rents a relatively small area in the market as a mini post office. The stuff who works for POSTEN may also the stuff of this supermarket. The advantages of this business partnership relation are: saving both facility and labour cost, improving facility efficiency, accessibility. People do not need shopping and receive package at two different places. And at the same time partnership between POSTEN and supermarket brings customers for both. In addition, supermarket is the place where everyone comes very often. Therefore, from the customer's point of view, it is a smart, creative and efficient decision for POSTEN. At present, there are two sites that provide postal services in the city.

5.3 City map analysis

Owing to postal service network mainly provide services to residents of this city, it is always smart to study the city map and extract valuable information. The map of NARVIK city with plotting scale equal to 200 m downloaded from google is shown in figure 22. The yellow line represents the #6 European route which across trough NARVIK from south to north and vice versa. Grey colour on the map refers to buildings and the city centre is marked in the middle.

In order to simplify the analysis work, a city map contains 40 cells is provided behind in figure 23. 40 cells are exactly the same with size that [L x H] = [3 x 2.9]

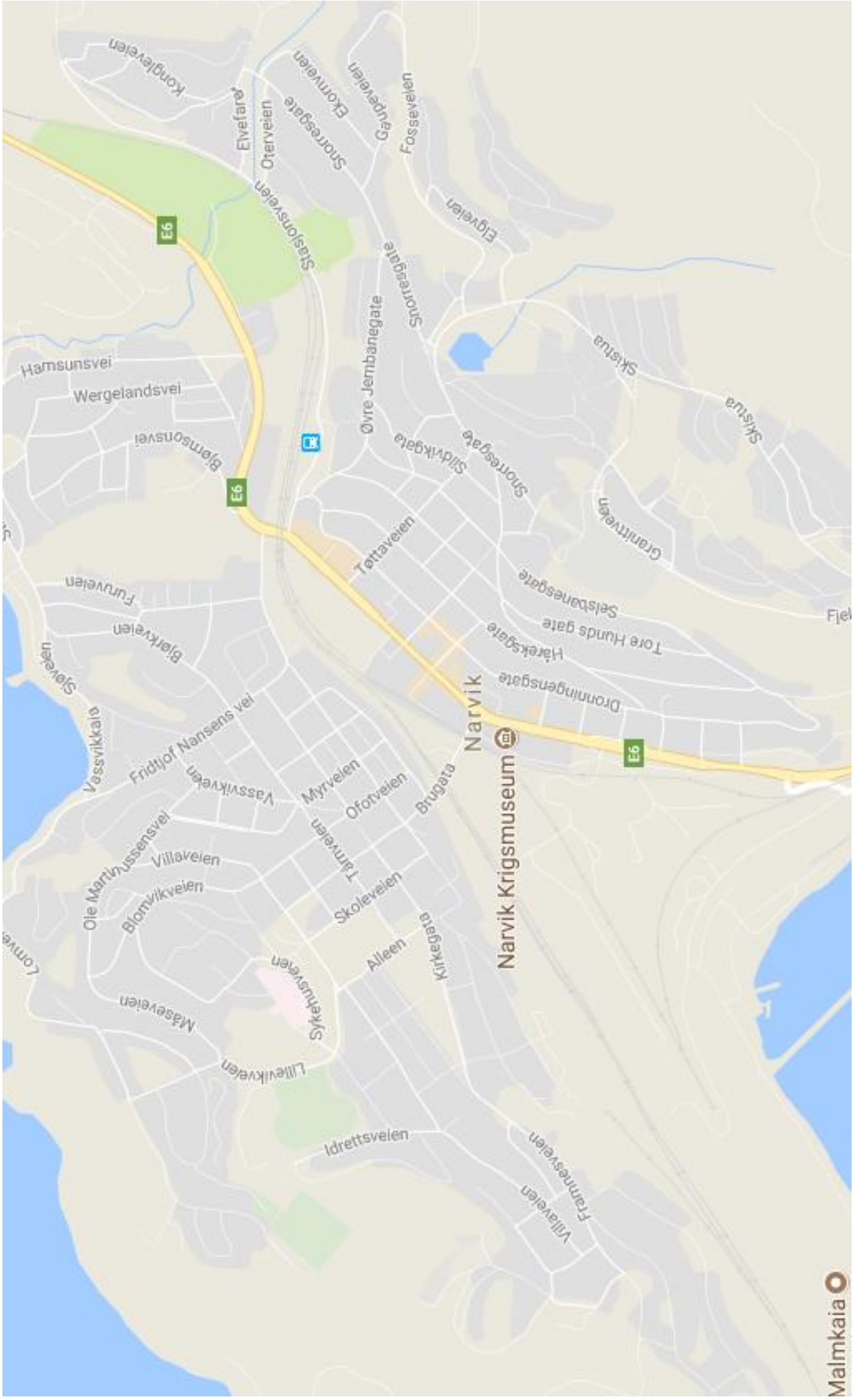


Figure 22 Google Map of NARVIK

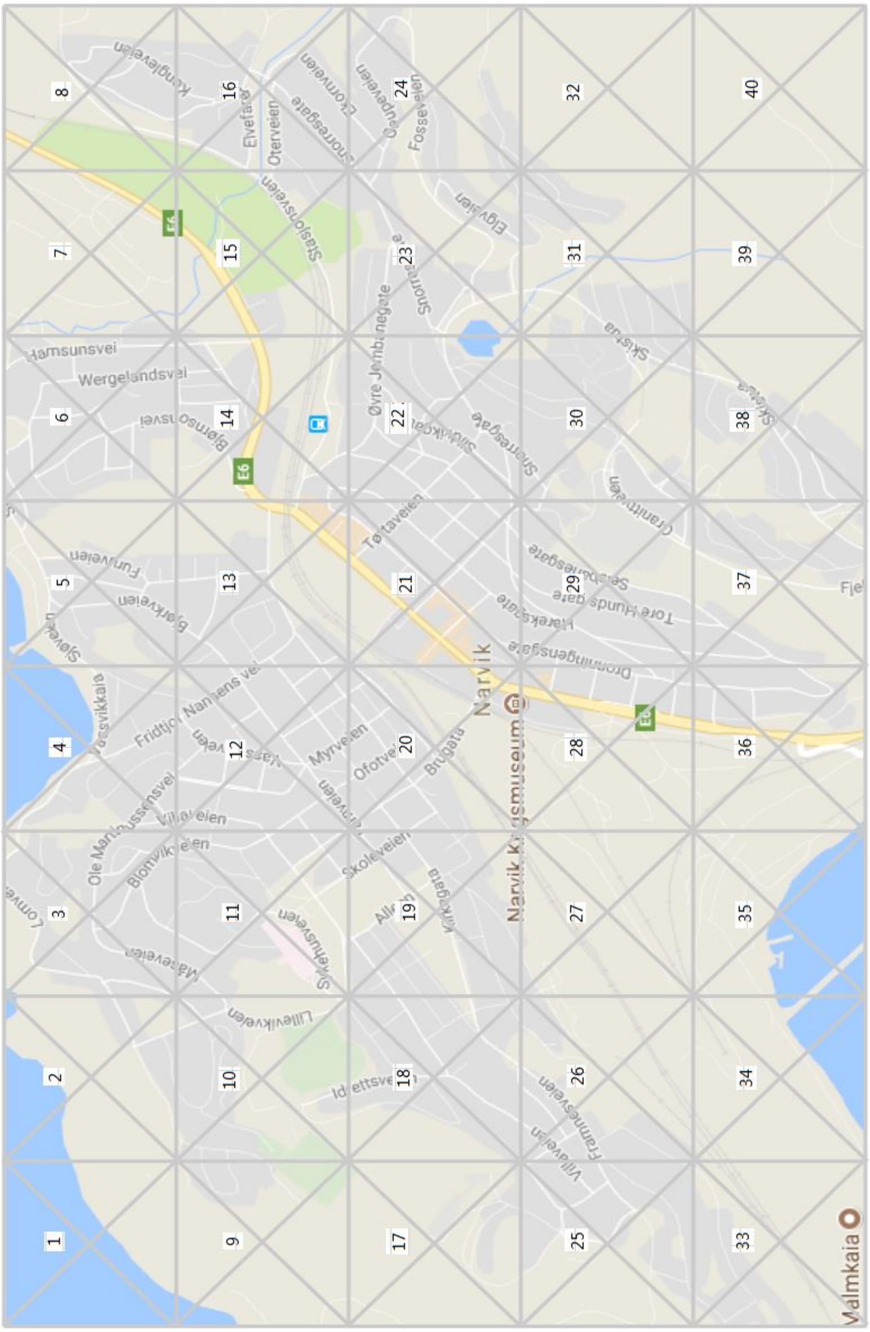


Figure 23 Map of NARVIK contains 40 cells

Thus, the total length of map is 24 m and height is 14.5 m. Assuming the coordinates of left bottom point is (0, 0), then centre point of cell 33 is (1,5 1,45), cell 34 (4.5 1.45) and cell 25(1.5 4.5). The reason for calculating the coordinates for all 40 the centre point is that if a reader zooms out the map, then 40 cells on the map can be considered as 40 demand points with coordinates.

For obtain the distance matrix, Manhattan measuring method is applied. Manhattan refers to the distance between two points measured along axes at right angles, which is applied widely in transportation research. To measure distance between p1 at (x1, y1) and p2 at (x2, y2), it is |x1 - x2| + |y1 - y2|. By applying the plotting scale equal to 200m, the real distance which between nodes candidates shown in figure 24.

Distance	3	4	5	6	7	8	10	11	12	13	14	16	18	19	20	21	22	23	24	25	26	28	29	30	31	33	38
3	0	400	800	1200	1600	2000	787	387	787	1187	1587	2387	1173	773	1173	1573	1973	2373	2773	1960	1560	1560	1960	2360	2760	2347	2747
4	400	0	400	800	1200	1600	1187	787	387	787	1187	1987	1573	1173	773	1173	1573	1973	2373	2360	1960	1160	1560	1960	2360	2747	2347
5	800	400	0	400	800	1200	1587	1187	787	387	787	1587	1973	1573	1173	773	1173	1573	1973	2760	2360	1560	1160	1560	1960	3147	1947
6	1200	800	400	0	400	800	1987	1587	1187	787	387	1187	2373	1973	1573	1173	773	1173	1573	3160	2760	1960	1560	1160	1560	3547	1547
7	1600	1200	800	400	0	400	2387	1987	1587	1187	787	787	2773	2373	1973	1573	1173	773	1173	3560	3160	2360	1960	1560	1160	3947	1947
8	2000	1600	1200	800	400	0	2787	2387	1987	1587	1187	387	3173	2773	2373	1973	1573	1173	773	3960	3560	2760	2360	1960	1560	4347	2347
10	787	1187	1587	1987	2387	2787	0	400	800	1200	1600	2400	387	787	1187	1587	1987	2387	2787	1173	773	1573	1973	2373	2773	1560	2760
11	387	787	1187	1587	1987	2387	400	0	400	800	1200	2000	787	387	787	1187	1587	1987	2387	1573	1173	1173	1573	1973	2373	1960	2360
12	787	387	787	1187	1587	1987	800	400	0	400	800	1600	1187	787	387	787	1187	1587	1987	1973	1573	773	1173	1573	1973	2360	1960
13	1187	787	387	787	1187	1587	1200	800	400	0	400	1200	1587	1187	787	387	787	1187	1587	2373	1973	1173	773	1173	1573	2760	1560
14	1587	1187	787	387	787	1187	1600	1200	800	400	0	800	1987	1587	1187	787	387	787	1187	2773	2373	1573	1173	773	1173	3160	1160
16	2387	1987	1587	1187	787	387	2400	2000	1600	1200	800	0	2787	2387	1987	1587	1187	787	387	3573	3173	2373	1973	1573	1173	3960	1960
18	1173	1573	1973	2373	2773	3173	387	787	1187	1587	1987	2787	0	400	800	1200	1600	2000	2400	787	387	1187	1587	1987	2387	1173	2373
19	773	1173	1573	1973	2373	2773	787	387	787	1187	1587	2387	400	0	400	800	1200	1600	2000	1187	787	787	1187	1587	1987	1573	1973
20	1173	773	1173	1573	1973	2373	1187	787	387	787	1187	1987	800	400	0	400	800	1200	1600	1587	1187	387	787	1187	1587	1973	1573
21	1573	1173	773	1173	1573	1973	1587	1187	787	387	787	1587	1200	800	400	0	400	800	1200	1987	1587	787	387	787	1187	2373	1173
22	1973	1573	1173	773	1173	1573	1987	1587	1187	787	387	1187	1600	1200	800	400	0	400	800	2387	1987	1187	787	387	787	2773	773
23	2373	1973	1573	1173	773	1173	2387	1987	1587	1187	787	787	2000	1600	1200	800	400	0	400	2787	2387	1587	1187	787	387	3173	1173
24	2773	2373	1973	1573	1173	773	2787	2387	1987	1587	1187	387	2400	2000	1600	1200	800	400	0	3187	2787	1987	1587	1187	787	3573	1573
25	1960	2360	2760	3160	3560	3960	1173	1573	1973	2373	2773	3573	787	1187	1587	1987	2387	2787	3187	0	400	1200	1600	2000	2400	387	2387
26	1560	1960	2360	2760	3160	3560	773	1173	1573	1973	2373	3173	387	787	1187	1587	1987	2387	2787	400	0	800	1200	1600	2000	787	1987
28	1560	1160	1560	1960	2360	2760	1573	1173	773	1173	1573	2373	1187	787	387	787	1187	1587	1987	1200	800	0	400	800	1200	1587	1187
29	1960	1560	1160	1560	1960	2360	1973	1573	1173	773	1173	1973	1587	1187	787	387	787	1187	1587	1600	1200	400	0	400	800	1987	787
30	2360	1960	1560	1160	1560	1960	2373	1973	1573	1173	773	1573	1987	1587	1187	787	387	787	1187	2000	1600	800	400	0	400	2387	387
31	2760	2360	1960	1560	1160	1560	2773	2373	1973	1573	1173	1173	2387	1987	1587	1187	787	387	787	2400	2000	1200	800	400	0	2787	787
33	2347	2747	3147	3547	3947	4347	1560	1960	2360	2760	3160	3960	1173	1573	1973	2373	2773	3173	3573	387	787	1587	1987	2387	2787	0	2000
38	2747	2347	1947	1547	1947	2347	2760	2360	1960	1560	1160	1960	2373	1973	1573	1173	773	1173	1573	2387	1987	1187	787	387	787	2000	0

Figure 24 Matrix of distance between points

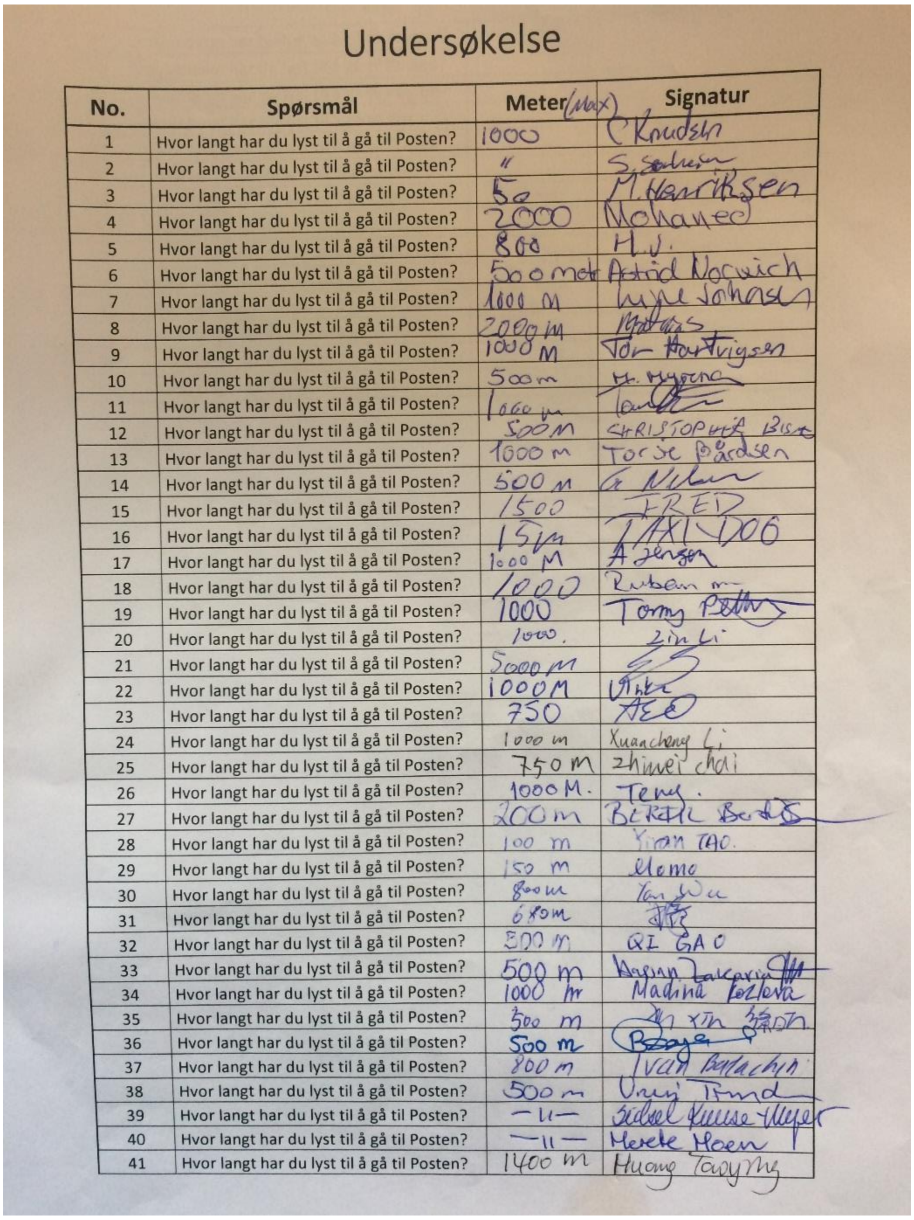
The method of finding demand matrix is that evaluating the building distribution in each cell, and then translate it into population distribution for each cell. Demand matrix showed in figure 25. Notice that some points are not included in to the demand matrix because of the demand ratio are very low (i.e. the percentage of building distribution in the cell lower than 20%)

Weight		
3	0.7	726
4	0.6	623
5	0.5	519
6	0.9	934
7	0.5	519
8	0.4	415
10	0.4	415
11	0.7	726
12	1.0	1038
13	0.5	519
14	0.7	726
16	0.7	726
18	0.8	830
19	0.8	830
20	0.5	519
21	0.9	934
22	1.0	1038
23	0.8	830
24	0.6	623
25	0.5	519
26	0.4	415
28	0.8	830
29	1.0	1038
30	0.8	830
31	0.4	415
33	0.3	311
38	0.6	623
SUM	17.8	18473

Figure 25 Matrix of demand

Before start simulating, there is still one important parameter needed to be defined, d_s. The method of defining the distance coverage for this paper in to do a survey. Survey example shown in figure 26 below. The question of the survey is to ask: "what is longest distance you can tolerant if you have to walk to the post office in NARVIK?" After inquiring 100 residents randomly with their signatures in NARVIK, the coverage distance is 900 meters i.e. d_s=900 meter in this case.

In addition, due to large size of matrix computation, the original solver embedded in Excel cannot operation. Thus, an Excel VBA add-in call Open Solver with more powerful solver was applied to help in this paper. The interface of Open Solver seems very like the original one, easy for operation.



Undersøkelse

No.	Spørsmål	Meter (max)	Signatur
1	Hvor langt har du lyst til å gå til Posten?	1000	C Knudsen
2	Hvor langt har du lyst til å gå til Posten?	"	[illegible]
3	Hvor langt har du lyst til å gå til Posten?	50	M. Henriksen
4	Hvor langt har du lyst til å gå til Posten?	2000	Mohamed
5	Hvor langt har du lyst til å gå til Posten?	800	H.J.
6	Hvor langt har du lyst til å gå til Posten?	500 meter	Astrid Norwich
7	Hvor langt har du lyst til å gå til Posten?	1000 m	[illegible] Johansen
8	Hvor langt har du lyst til å gå til Posten?	2000 M	Mathias
9	Hvor langt har du lyst til å gå til Posten?	1000 M	Tor Hartvigsen
10	Hvor langt har du lyst til å gå til Posten?	500 m	[illegible]
11	Hvor langt har du lyst til å gå til Posten?	1000 m	[illegible]
12	Hvor langt har du lyst til å gå til Posten?	500 M	CHRISTOPHER Bist
13	Hvor langt har du lyst til å gå til Posten?	1000 m	Torje Bårdsen
14	Hvor langt har du lyst til å gå til Posten?	500 m	G. Nilsen
15	Hvor langt har du lyst til å gå til Posten?	1500	FRED
16	Hvor langt har du lyst til å gå til Posten?	15 m	TAXI DOG
17	Hvor langt har du lyst til å gå til Posten?	1000 M	A Jensen
18	Hvor langt har du lyst til å gå til Posten?	1000	Ruben m
19	Hvor langt har du lyst til å gå til Posten?	1000	Tommy Petter
20	Hvor langt har du lyst til å gå til Posten?	1000.	Zin Li
21	Hvor langt har du lyst til å gå til Posten?	5000 M	[illegible]
22	Hvor langt har du lyst til å gå til Posten?	1000M	[illegible]
23	Hvor langt har du lyst til å gå til Posten?	750	AEO
24	Hvor langt har du lyst til å gå til Posten?	1000 m	Xuancheng Li
25	Hvor langt har du lyst til å gå til Posten?	750 M	Zhiwei Chai
26	Hvor langt har du lyst til å gå til Posten?	1000 M.	Teny.
27	Hvor langt har du lyst til å gå til Posten?	200 m	BERTIL [illegible]
28	Hvor langt har du lyst til å gå til Posten?	100 m	Yiran TAO.
29	Hvor langt har du lyst til å gå til Posten?	150 m	Momo
30	Hvor langt har du lyst til å gå til Posten?	800 m	Yan Wu
31	Hvor langt har du lyst til å gå til Posten?	680 m	[illegible]
32	Hvor langt har du lyst til å gå til Posten?	500 m	QI GAO
33	Hvor langt har du lyst til å gå til Posten?	500 m	[illegible] Zakaria
34	Hvor langt har du lyst til å gå til Posten?	1000 m	Madina Kozlova
35	Hvor langt har du lyst til å gå til Posten?	500 m	[illegible]
36	Hvor langt har du lyst til å gå til Posten?	500 m	[illegible]
37	Hvor langt har du lyst til å gå til Posten?	800 m	Ivan Barlachin
38	Hvor langt har du lyst til å gå til Posten?	500 m	[illegible]
39	Hvor langt har du lyst til å gå til Posten?	-"-	Sidsel Kruse-Meyer
40	Hvor langt har du lyst til å gå til Posten?	-"-	Merete Moen
41	Hvor langt har du lyst til å gå til Posten?	1400 m	Huong [illegible]

Figure 26 Example of survey (page 1/3)

5.4 Postal facilities location modelling by applying SCLP

Since ds= 900, the subset along with under covered building are listed in figure 27 which can be applied to build constrains in SCLP and ensuring each demand node is covered by at least on facility.

Set distance coverage = 900	
Subset	Covers
3	3,4,5,10,11,12,19
4	3,4,5,6,11,12,13,20
5	3,4,5,6,7,12,13,14,21
6	4,5,6,7,8,13,14,22
7	5,6,7,8,14,16,23
8	6,7,8,16,24
10	3,10,11,12,18,19,26
11	3,4,10,11,12,13,18,19,20
12	3,4,5,10,11,12,13,14,19,20,21,28
13	4,5,6,11,12,13,14,20,21,22,29
14	5,6,7,12,13,14,16,21,22,23,30
16	7,8,14,16,23,24
18	10,11,18,19,20,25,26
19	3,10,11,12,18,19,20,21,26,28
20	4,11,12,13,18,19,20,21,22,28,29
21	5,12,13,14,19,20,21,22,23,28,29,3[illegible]
22	6,13,14,20,21,22,23,24,29,30,31,3[illegible]
23	7,14,16,21,22,23,24,30,31
24	8,16,22,23,24,31
25	18,25,26,33
26	10,18,19,25,26,28,33
28	12,19,20,21,26,28,29,30
29	13,20,21,22,28,29,30,31,38
30	14,21,22,23,28,29,30,31,38
31	22,23,24,29,30,31,38
33	25,26,33
38	22,29,30,31,38

Figure 27 Relationship between subset and its coverage

Decision Variables		Constrains					
3	0	Node3	1	>=	1		
4	0	Node4	1	>=	1		
5	0	Node5	1	>=	1		
6	0	Node6	2	>=	1		
7	0	Node7	1	>=	1		
8	1	Node8	1	>=	1		
10	1	Node10	2	>=	1		
11	0	Node11	2	>=	1		
12	0	Node12	2	>=	1		
13	1	Node13	1	>=	1		
14	0	Node14	1	>=	1		
16	0	Node16	1	>=	1		
18	0	Node18	2	>=	1		
19	0	Node19	1≤ 2	>=	1		
20	0	Node20	1	>=	1		
21	0	Node21	1	>=	1		
22	0	Node22	2	>=	1		
23	0	Node23	1	>=	1		
24	0	Node24	2	>=	1		
25	0	Node25	1	>=	1		
26	1	Node26	2	>=	1		
28	0	Node28	1	>=	1		
29	0	Node29	2	>=	1		
30	0	Node30	1	>=	1		
31	1	Node31	1	>=	1		
33	0	Node33	1	>=	1	Objective Function	min
38	0	Node38	1	>=	1	Z	2179
Nr.	5						

Figure 28 The minimum number of facilities located in SCLP

Save the processes in between, after running the computing in Open Solver, figure 28 shows that if coverage distance is 900 m, then there are at least 5 postal need to be set to make sure all demand are covered by postal service network in NARVIK. Total weighted cost equal to 2179, and the locations of these building are in 8,10,13,26,31 separately.

5.5 Postal facilities location modelling by applying MCLP

Set Ds = 900, then

Table 10 – Relationships between number of facilities and Covering Rate

Number of P facility	Facility Locations	Weight covering	Covering Rate
1	11	12971	70.22%
2	8, 11	16188	87.64%
3	5,18,24	17537	94.94%
4	11,16,22,25	18471	100%
5	6,19,23,25,31	18471	100%

5.6 Postal facilities location modelling by applying p-median

Table 11 – relationship weighted average distance and number of facility needed

Number of given facilities	Building Locations	Demand-weight total distance	Demand-weighted average distance (Demand-weighted total distance/tot. demand)
1	21	18318973	991.7694
2	19, 22	12633773	683.9788
3	12,18,22	10263133	555.635
4	12, 16,18, 22	8450960	457.5259
5	6,12,18,23,29	6875960	372.2571
6	6,12,18,24,29,30	6067787	328.5034
7	6,11,12,24,26,29,30	5320987	288.0725

This table 11 shows the same result which is the demand-weighted average distance is inversely proportional to the number of facilities opened.

6. Conclusion and future study

6.1 Outcome analysis

As mentioned in chapter, there are totally 2 sites provide postal services in NARVIK. Both are opened inside a supermarket and the positions illustration are show in figure 29 below.

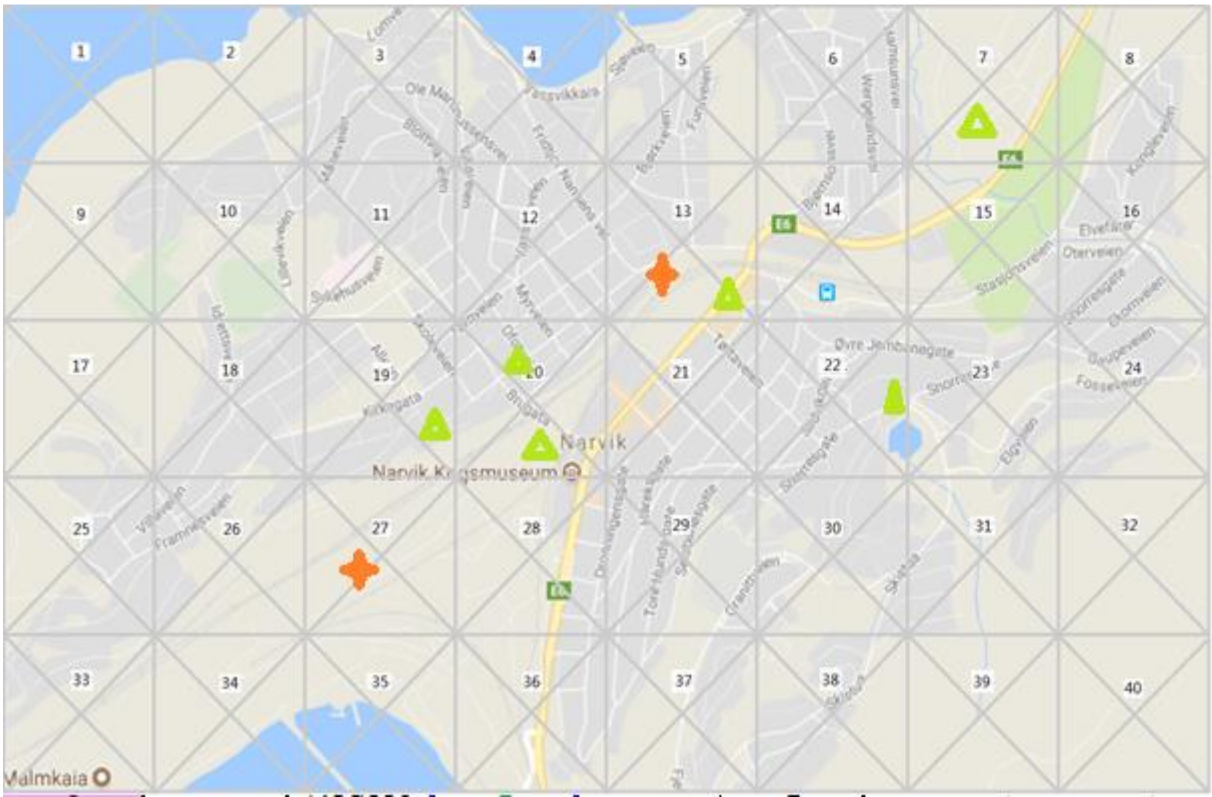


Figure 29 Map with marks

As shown in figure 29, eight supermarkets marked on the map. In cell 13 and cell 27, two supermarkets art marked with red star means residents can accept postal services in either of these two places. Markets market by green means no partner relations with POSTEN.

Table 12– Comparison simulation outcomes existing facility location

Number of facility	Existing facility locations in map	According to MCLP	Advantage (High-coverage)	According to p-median	Advantage of p- median
Two	27 & 13	8 & 11	87.64% coverage	19 & 22	684 demand-weighted avg. distance
Three	---	5 & 18 &24	95% coverage	12 & 18 & 22	556 demand-weight avg. distance

The result based on set covering location model shows that the city needs at least five postal service sites in order to cover all customers if facilities can locate at cell 8, 10,13,26 and cell 31. No less. This method only be accepted to full coverage or zero coverage, no compromise in between, which is a too extreme. The objective of set covering location model seeks to have a full coverage with minimum number of service facilities. This may lead to high investment cost, low accessibility or responsiveness. Unless, the customer demands increase rapidly, the service provider will not open 3 more service facilities tomorrow. Besides this new service pattern by partnering with supermarket is doing good. In this case, this paper would like to put aside the result of set covering location model and focuses on the comparison the results among maximal covering model, p-median model and the existing service locations.

As shown in table 12. Under the condition of two facilities allowed, service provider can be located facilities at cell 8 and 11 to increase the total customer demand. But the disadvantage is there are no shops or supermarket near around. To open a new facility will increase the cost more than to find one more partner. And according to p-media modelling, the accessibility for customers are increase while average demand-weight distance decreases until 684 meters which is much lower than the coverage distance ds in this case. The two location points according to p-median method are within cell 19 and cell 22, both contain a supermarket on the map Therefore, high accessibility and low investment may push POSTEN reconsider about.

If POSTEN want to remain the existing two post sites but want to open a new site because of the increasing customer demand. In this case, the outcome of maximal covering location model and p-median model has a mutual solution with both high coverage rate for service facility and high accessibility for customers. And the location of this point is in cell 18.

6.2 Conclusion and Future work

How to find a balance for efficiency, accessibility and availability was, is and will always be a conflict service between providers and customers. Paper introduces three classic mathematical models to represent three concepts respectively. Through a real-world case study about the performance of postal service network, a deeper understanding given to author.

The future work is to continue base on efficiency, accessibility and availability, studying more advanced mathematical model and analysing tool for large scale size of problem. For instance, an analysis of postal service network in order to improve the service level in whole Norway.

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